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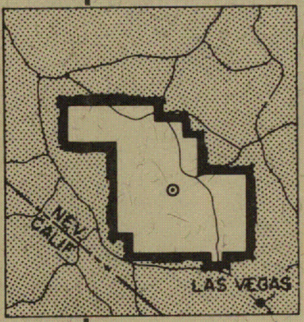

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Project 32.1

PROTECTION AGAINST FALLOUT RADIATION IN A SIMPLE STRUCTURE

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CIVIL EFFECTS TEST GROUP

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Report to the Test Director

PROTECTION AGAINST FALLOUT RADIATION IN A SIMPLE STRUCTURE

By

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Health and Safety Laboratory
New York Operations Office
April 1962

ABSTRACT

A reinforced Butler building was exposed to fallout from Shots Diablo and Shasta, and the resulting dose rates and fallout deposition inside and outside the structure were measured with various instruments and techniques.

Protection factors and roof and ground contributions to the total dose rates at points within the structure were determined from the measurements. Comparisons were made with the results of theoretical and other experimental studies.

Information obtained from this experiment should be of value as basic experimental data for fallout protection work, although it is recommended that additional substantiative data be obtained under more controlled conditions.

ACKNOWLEDGMENTS

The authors wish to express their appreciation to the many persons without whose assistance the experimental work and the analysis of samples and data could not have been performed.

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Chapter 1

INTRODUCTION

1.1 OBJECTIVE

This experiment was designed to obtain field measurements of gamma-radiation intensities from actual local fallout in and around a simple structure in such a way that the dose-rate attenuation could be described temporally and spatially.

For proper interpretation of these measurements, the following additional information was sought:

1. Identification of roof and grade contributions to the dose rate within the structure.
2. Fallout activity per unit area of ground and roof surface.
3. Effective energy of primary radiation and of scattered radiation.

The experimental work was performed at Operation Plumbbob during 1957 at the Nevada Test Site (NTS).

1.2 BACKGROUND

Shelter, as an aid to survival in an area of heavy fallout following an atomic attack, has been widely discussed and recommended. Measured and estimated radiation patterns from fallout following atomic bursts have led civil-defense planners to speak of a protection factor of 100 or, in some circumstances, 1000 times as the minimum requirement for safety. A building would have a protection factor of 2 if an individual were exposed in the building to one-half the radiation dose outside the building in an open area. An underground shelter covered with about 3 ft of earth would have a protection factor of about 1000 times.[1] Such a shelter, if properly designed, would provide some measure of protection against direct blast and thermal effects as well as against radiation.

In the absence of such shelters, it is desirable to seek alternate means of protection even though these may be less than ideal.

Any structure with a roof offers some protection against fallout radiation. In fact many of the larger, massive buildings have protection factors of 1000 or more in some inside locations. However, where a protection factor of 1000 might well be necessary in areas of greatest fallout intensity, a factor of 100, 10, or even less than 10 might provide the necessary margin of safety at the fringes of a fallout area. Factors in this range are to be found in existing conventional structures. It would be negligent to dismiss private residences, office and commercial buildings, and factories as potential shelters for as long as ideal shelters are essentially nonexistent. A number of investigators have advanced theories or performed experiments to analyze the protection factors within structures.[2-4] The objective of these studies has been to enable planners to evaluate the attenuation characteristics at various locations within typical buildings. It can be seen readily that this information would be useful to (1) select locations offering optimum protection against fallout radiation, (2) design added protection where existing structures are thought to be substandard, and (3) design new structures with a view toward incorporating protection areas.

Relatively few data from field tests in actual fallout are available to validate the various methods of attenuation evaluation that have been advanced. Empirical studies of fallout attenuation in structures have been conducted using point sources arrayed in a pattern to simulate the relatively uniform distribution in fallout. However, various assumptions that may introduce inaccuracies are inherent in empirical studies as well as in theoretical studies.

It is equally true that inaccuracies are inherent in any experiment performed at a weapons test, but to date no other method has been devised to exactly duplicate the deposition and energy-spectrum characteristics of fallout. Certain field experiments approach this, however. Measurements of attenuation at a natural fallout field are necessary before full confidence can be placed in attenuation estimates based on theoretical or point-source studies.

1.3 THEORY

For the purpose of this discussion, protection factor is defined as the ratio of the free-field gamma dose rate (radiation intensity at 3 ft above an infinite contaminated plane) to the gamma dose rate at any point of interest within a structure. Normally this ratio is greater than 1. For simplicity in visualizing fallout protection, one may consider that at any point within a structure the dose rate consists of two components: (1) radiation emitted from the ground around the structure, and (2) radiation emitted from fallout deposited on the roof of the structure. These two components are additive. For inside locations above grade, direct radiation emitted from fallout on the ground can be calculated readily. The scatter contribution to the dose rate can be accounted for by introducing a buildup factor or by adding a scatter component derived empirically. Calculations must account not only for the geometrical effect on the protection factor, mainly separation from a source, but also for additional attenuation effected by structural mass. The latter may be introduced by means of a shielding factor which is a function of the density and thickness of the structural material and the gamma energy.

The dose-rate contribution to the radiation field within the structure from contamination on the roof of the structure can be computed separately by following calculation procedures outlined above and then it can be added to the value obtained for ground-emitted radiation.

Because calculations of protection factor must be based upon mathematical models, uncertainties and inaccuracies are introduced when these calculations are applied to a practical structure even if it is relatively simple. One effect that is not completely understood is the modification of the radiation field by terrain. It is known, for instance, that the radiation field over the NTS terrain is considerably different from that which would be predicted assuming a perfectly smooth infinite plane.[5] It is not known by how much this effect may be different over other terrains with different degrees of roughness. Another complicating factor is the wide and changing energy spectrum of fission products, which imposes a difficulty in selecting a suitable energy value for use in the theoretical equations.

Calculations of protection factors at positions below grade (in a basement for instance) are subject to further uncertainties. Primary radiation from grade is reduced to insignificance in basements of practical size but scatter radiation from grade can be significant and must be accounted for. Very little data are available about the spectral composition and angular distribution of scatter; as a result the scatter values can only be approximated. Therefore, in essence the reason for conducting this experiment was to provide a field-determined checkpoint against which to compare other investigations that have been conducted on the basis of theory or simulated fallout sources. The values thus derived are not intended to have direct application in any practical civil-defense situation.

For typical calculations of fallout attenuation, the reader is referred to the several reports on this subject.[6–9]

Chapter 2

PROCEDURE

2.1 EXPERIMENTAL PLAN

The final design of the experiment evolved from a series of compromises which recognized the limitations and uncertainties of experimental work at the NTS. One underlying decision was to simplify the conditions of the experiment as much as possible. For instance, the effect of structural shielding was to be excluded so that geometrical attenuation alone could be examined. Therefore the specifications called for a superstructure with minimal shielding properties. Furthermore, the geometry was to be simplified by selecting a symmetrical structure (square plan). The ideal composition for the superstructure would have been canvas or some other strong fabric supported on a light metal framework. However, because the structure had to be located close enough to Ground Zero (GZ) to assure adequate fallout for meaningful measurements, a conflicting requirement for strength to withstand blast damage was introduced. The compromise structure selected for the test was a standard, commercial, sheet-metal-clad, steel-frame building with steel-frame members added to augment its strength. The effect of the shielding properties of the building on attenuation measurements is discussed later in Sec. 2.2. An experimental requirement for measuring protection factors both with and without contributions from fallout on the roof was that the roof of the building lend itself to rapid and virtually perfect decontamination. This requirement was met by laying $\frac{1}{4}$-in. demountable plywood paneling in sections over the entire roof surface. The panels were individually fastened to the roof by machine screws and wing nuts which could be unfastened rapidly by hand.

The experimental procedure consisted in (1) exposing the structure to fallout, (2) obtaining radiation-intensity measurements within and around the building following the cessation of fallout, (3) removing the plywood panels, and (4) repeating the radiation-intensity measurements within the building. Steps 2, 3, and 4 were accomplished in rapid succession during a single recovery mission enduring for no more than 1 hr, although subsequent entries were made to repeat radiation measurements at different times after each event. From these measurements protection factors could be computed for various locations within the structure with both the presence and the absence of the roof source of radiation. The roof and grade components of the radiation dose rates could be identified by subtraction.

Radiation intensities were measured with portable survey instruments and with fixed-position, continuously recording radiation monitors. These measurements were supplemented by film packs suspended in a close array within the building with a first set exposed until the roof was removed and then with a second set replacing the first after roof removal. Measurements of fallout deposition were obtained with horizontal sheets of gummed film set in a geometrical pattern on the roof, on the ground around the structure, and in the basement. The project participated in three shots in the Plumbbob series; Diablo, Shasta, and Fizeau. In shot Fizeau recovery teams had to pass through an area that had received a large amount of fallout activity. By the time access through this area was permitted to the recovery teams, the radiation at the experimental site was too low for meaningful measurements, although some were taken. Therefore no data from shot Fizeau are included in this report.

The complete experimental field-test plan was conducted according to the following outline:*

1. Prior to shot
   (a) Place, activate, and calibrate fixed radiation monitoring instruments both inside and outside the structure.
   (b) Place initial strings of film packs inside the structure.
   (c) Place gummed-film trays on the roof inside and outside the structure.
   (d) Place Lucite absorber columns inside and outside the structure.
   (e) Place filters in automatic sequential air samplers inside and outside the structure.
   (f) Calibrate portable survey instruments at Mercury.
2. First recovery
   (a) Remove initial strings of film packs, place second set of strings.
   (b) Remove initial film packs from Lucite absorber columns, replace with second set of film.
   (c) Remove filters from sequential air samplers.
3. Second recovery
   (a) Calibrate portable survey instruments.
   (b) Remove second string of film packs.
   (c) Remove second film packs from Lucite absorber columns.
   (d) Remove gummed-film trays from roof inside and outside the structure.
   (e) Take measurements with portable survey instruments on the roof inside and outside the structure.
   (f) Remove plywood covering from roof.
   (g) Take measurements with portable survey instruments on the roof inside and outside the structure.
   (h) Place third set of film packs in Lucite absorber columns.
   (i) Place third set of strings of film packs.
4. Subsequent recoveries
   (a) Calibrate portable survey instruments.
   (b) Take measurements with portable survey instruments inside and outside the structure.
5. Last recovery
   (a) Calibrate portable survey instruments.
   (b) Remove third set of strings of film packs.
   (c) Remove third film packs from Lucite absorber columns.
   (d) Take measurements with portable survey instruments inside and outside the structure.
   (e) Remove strip charts from recording radiation monitors.

2.2 STRUCTURE

The experimental structure was a conventional Butler building, strengthened with additional vertical steel-frame members to withstand the anticipated blast pressures. The plan was a square measuring 32 by 32 ft; the height to the eaves from grade was 9 ft 9 in. and the height to the ridge of the roof was 15 ft. Wall and roof covering consisted of 26-gauge high-rib panels. Mounted on the roof were $\frac{1}{4}$-in.-thick plywood panels fastened with machine screws and wing nuts. The end walls were fastened by 1-ft-diameter tie rods to concrete deadmen for additional structural strength. The foundation consisted of 18-in.-thick poured-concrete walls enclosing a basement area measuring 29 by 29 by 7 ft. Over the basement at floor level were 2 by 8-in. wooden struts placed at 6-ft intervals and covered with a few wooden planks to serve as walkways. A diagram of the experimental structure is shown in Fig. 2.1 and a photograph in Fig. 2.2 (also in Refs. 10, 11, and 12).

The optimum distance for the structure from GZ was approximately 10,000 ft. This distance represented a compromise of the two conflicting weapons-effects considerations: blast-

* Slight variations in the plan occurred among the three participating shots.

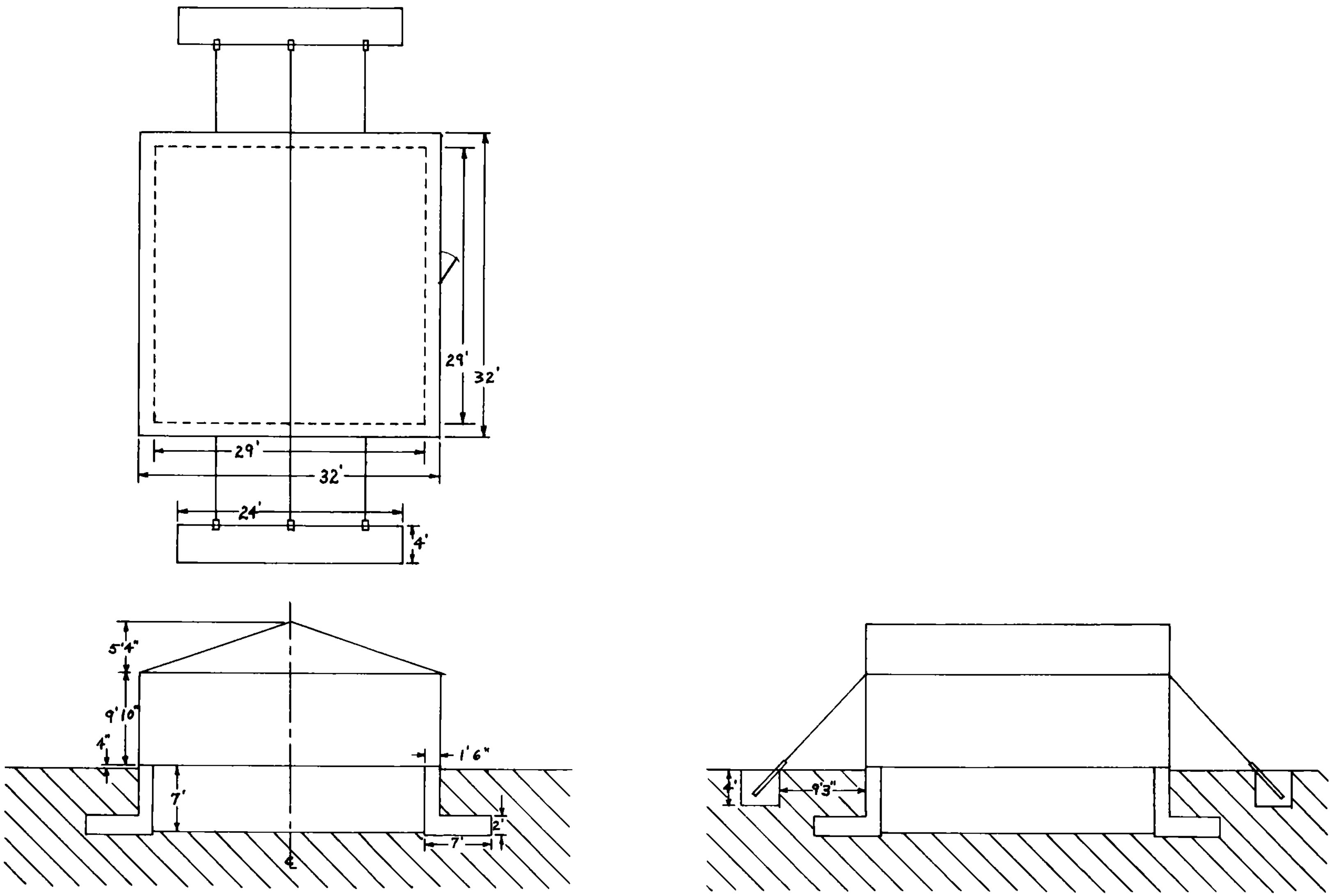

Fig. 2.1—Butler building layout.

Fig. 2.2—Butler building showing slight blast damage from Diablo.

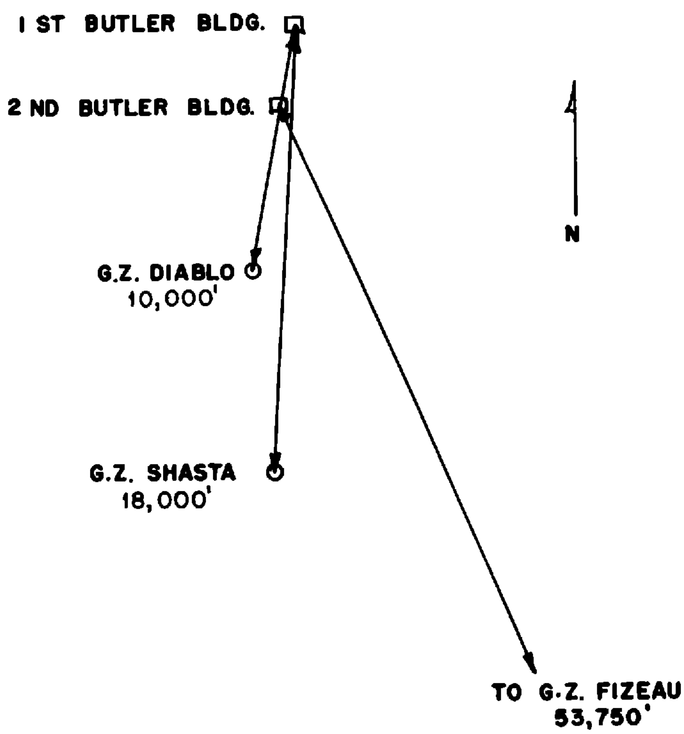

Fig. 2.3—Location of Butler buildings and Ground Zeros.

damage and fallout intensity. Therefore two structures were built for Project 32.1. The first, erected prior to the Diablo event, was 10,000 ft in a prevailing downwind direction from the shot Diablo tower. This was a favorable position with respect to shot Shasta as well.

After the Shasta event, a second similar structure was erected at a location favorable with respect to the shot Whitney tower, the first structure being too distant to receive adequate fallout. Instead of shot Whitney, however, the third participating shot was changed to shot Fizeau, the tower of which was over 10 miles away from both structures. Figure 2.3 shows the positions of the two structures with respect to the GZ's of shots Diablo, Shasta, and Fizeau.

The building for which data from the Diablo and Shasta events are reported was located on a gentle downward slope of northwest to southeast orientation. Near both ends of the building, earth was pushed into low piles as the result of excavations for the concrete deadmen, creating a significant deviation from a smooth plane surface. Attempts to remedy this undesirable situation were not successful.

Prior to shot Diablo, two experiments were performed to obtain an estimate of the attenuation manifested by the Butler building walls. A Co^{60} gamma-ray source was placed at the center of the building and the resulting dose rates in a traverse outside the building were measured. In the first case, three traverses were made, and in the second, two traverses were made. The mean dose rate was determined to be 81 per cent of the unattenuated value. This reduction in dose rate from Co^{60} gamma rays would be produced by 0.5 cm of iron. If the gamma-ray energy had been 0.7 Mev, a reduction to 76 per cent would have been expected. The conclusion derived was that the average attenuation due to barrier shielding at a point in the center of the structure for a distributed source on the ground outside the structure was about 25 per cent. This, of course, represents a marked departure from the desired minimal attenuation structure.

The structure was empty except for instrumentation and a power source which was provided by a 5-kw engine generator situated in one corner of the basement.

2.3 RADIATION MEASUREMENTS AND INSTRUMENTATION

The measurements of primary interest in this experiment were (1) radiation dose rates at 3 ft above the ground outside the test structure and at selected locations at various elevations inside the test structure, (2) fallout deposition per unit area on the structure roof, in the structure basement, and on the ground outside the structure. Supplementary measurements were obtained in an attempt to estimate the effective energy and to determine the air-dust concentrations inside and outside the structure.

2.3.1 Dose-rate Instrumentation

(a) *Jordan Instruments* A Jordan RAMS-2 monitoring system consisting of 15 Neher-White ionization chambers connected by cables to a central readout and recording console in the basement provided continuous gamma dose-rate measurements. Three chambers were placed outside the structure at a distance of 50 ft on radials 120° apart, and 12 chambers were suspended at selected locations within the structure. Figure 2.4 illustrates the positions of the 12 chambers inside the structure, and Fig. 2.5 illustrates the positions of the 3 chambers outside the structure.

The range covered by the instruments included five decades in a quasilogarithmic response from 0.1 mr/hr to 10 r/hr. The chambers were calibrated in the structure basement for each experiment using two Co^{60} sources with activities of 2 and 270 mc, respectively. Calibration values were obtained at seven intensities up to about 5 r/hr over the range of the instruments.

Each ionization chamber, as it was delivered to NTS for the first test structure, contained an automatic internal check source designed to expose the chamber to an intensity equivalent to 10 r/hr for 5 min every 6 hr on an automatic basis. However, in preliminary calibrations it was noted that the check source produced sufficient background radiation while in its off position to interfere with the response of the ionization chambers at their most sensitive range. For this reason all check sources were removed with the result that instrument calibration checks could not be obtained automatically during the course of the experiment. The lack of this feature seriously compromised the value of the measurements by these instruments because later field experiments revealed pronounced meter drift.

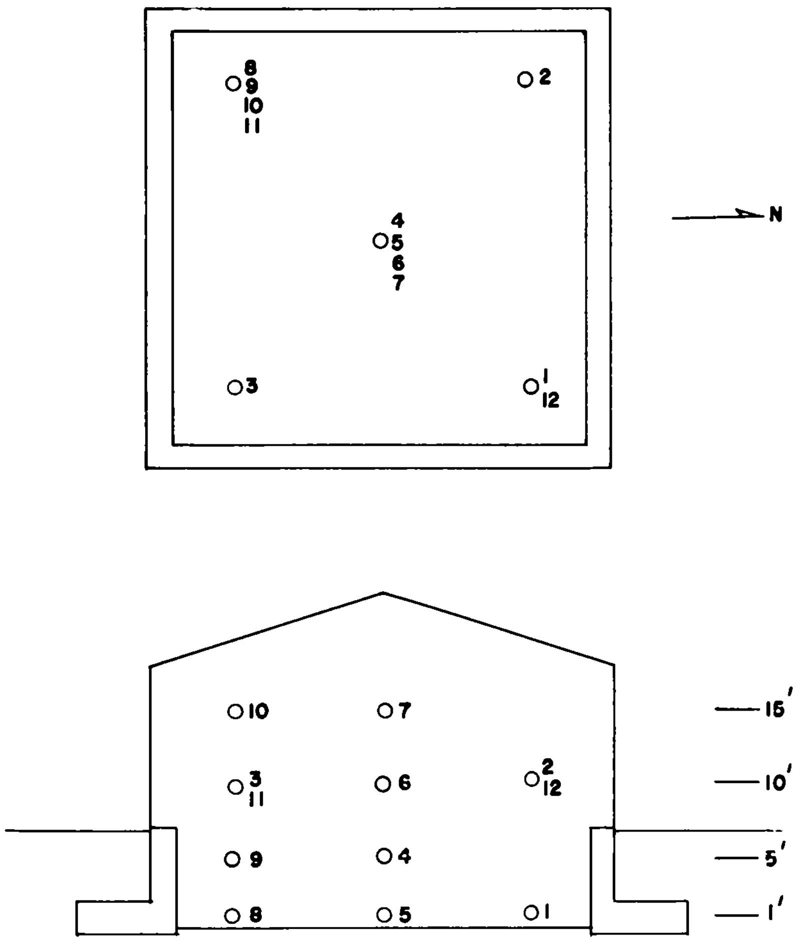

Fig. 2.4—Jordan instrument layout (inside). Refer to App. A for additional sample identification.

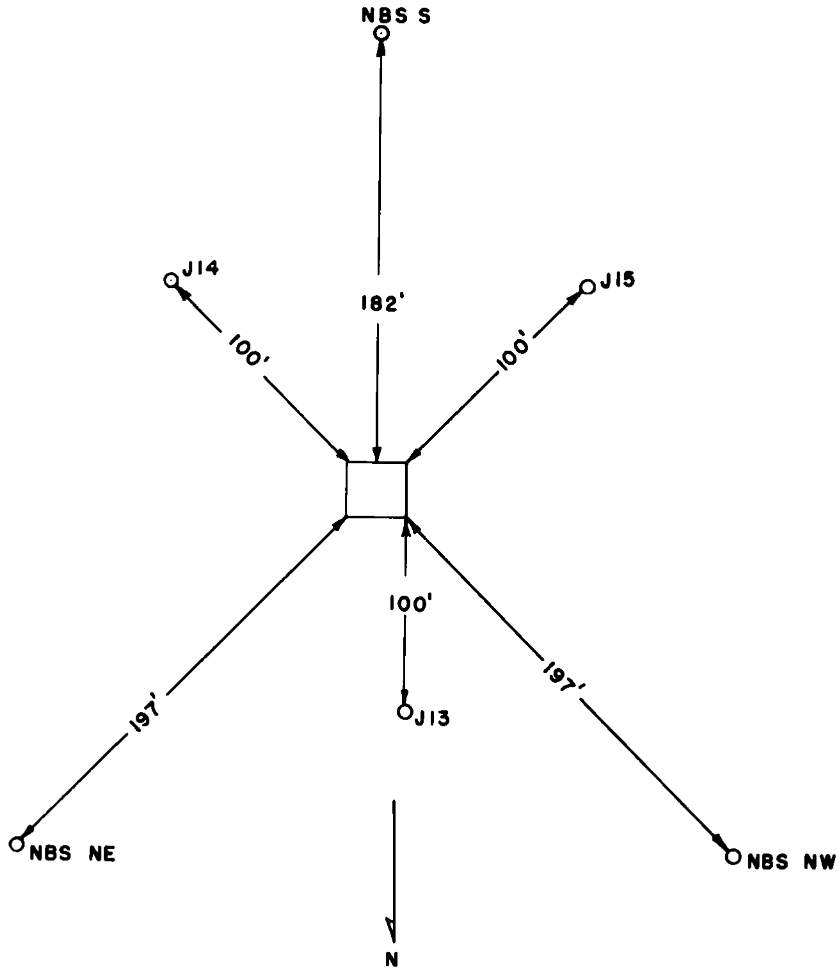

Fig. 2.5—Jordan and NBS instrument layout (outside). Refer to App. A for additional sample identification.

(b) *Portable Survey Instruments* Surveys were performed with portable radiation instruments during recovery operations and subsequent entries to the structure following fallout deposition. Used for this purpose were the Juno, AEC Model SIC-17C Ionization Chamber instrument with ranges of 0 to 50, 0 to 500, and 0 to 5000 mr/hr, and the Nuclear Instrument and Chemical Corp. model 2610 G-M survey instrument with ranges of 0 to 0.2, 0 to 2, and 0 to 20 mr/hr.

The portable survey instruments were employed to obtain more detailed radiation intensity data within the structure than was possible with a limited number of Jordan ionization chambers. The pattern of measurement inside the building is indicated in Fig. 2.6. Similar patterns of measurement outside the building and on the roof of the structure are indicated in Figs. 2.7 and 2.8.

The survey instruments were calibrated at Camp Mercury using a 2-mc Co^{60} source. The G-M type survey meters were calibrated over a range of 0.1 to 15 mr/hr at eight intensities. The ionization type instruments (Juno) were calibrated over a range of 10 to 200 mr/hr at five intensities. Since the Juno was held in a vertical position for some measurements, position (gravity) effects were also noted during calibrations. Calibrations were repeated before each recovery.

(c) *National Bureau of Standards (NBS) Instruments* Four gamma monitoring instruments of NBS design were made available from the Civil Effects Test Group pool to supplement the Jordan units. There were requested by the project some weeks prior to scheduled participation when there was doubt that the Jordan units would be delivered in time for installation.* When the Jordan instrument delivery was made only a few days before the first shot, it was decided to retain the NBS monitors. These were G-M detectors encased in suitable shielding to flatten the energy-response characteristics. The G-M signals were telemetered by land line to a readout trailer situated near the Control Point. An instantaneous reading could be obtained from any of the four units by initiating a challenge from the trailer. Three units were located outside the test structure at a distance of 200 ft on radials 120° apart and the fourth unit was located several feet from the center of the south wall 3 ft above the basement floor (see Fig. 2.5).

2.3.2 Integrated Dose Measurements, Film Packs

Du Pont #502 film packs were suspended on strings within the structure to obtain more detailed radiation profiles than was possible with other measuring techniques. The packs were spaced at 1-ft intervals vertically from a height of 1 ft to a height of 14 ft from the basement floor at the locations shown in Fig. 2.9. This Du Pont film packet contains both a slow and a fast response film with an effective dose range of approximately 25 mr to 20 r.

One set of 2 strings and two sets of 11 strings were used for each event. All were brought to the structure the day before the event was scheduled and a small set was suspended in position and the others were stored in containers situated in one corner of the basement floor shielded with sandbags to minimize inadvertent radiation exposure. The first set was replaced with an unexposed set during the first recovery mission after the termination of fallout. The exposed films were immediately placed in the shielded containers in the basement. The second set was replaced by the other unexposed set at the time the roof panels were removed. These and the other exposed films were left in the shielded containers until the ambient radiation intensities had diminished substantially. Control film packs were placed in the containers to measure inadvertent exposure during storage. All films were sent to the Health and Safety Laboratory (HASL) in New York for processing.

2.3.3 Fallout Deposition, Gummed Film

Sheets of gummed film 1-ft square mounted on aluminum frames were placed at designated locations outside the structure, on the structure roof, and in the basement as shown in Figs. 2.10 and 2.11. For the outside and basement positions, frames were fastened to 3-ft-high

* This is no reflection on the vendor. The equipment was ordered on very short notice.

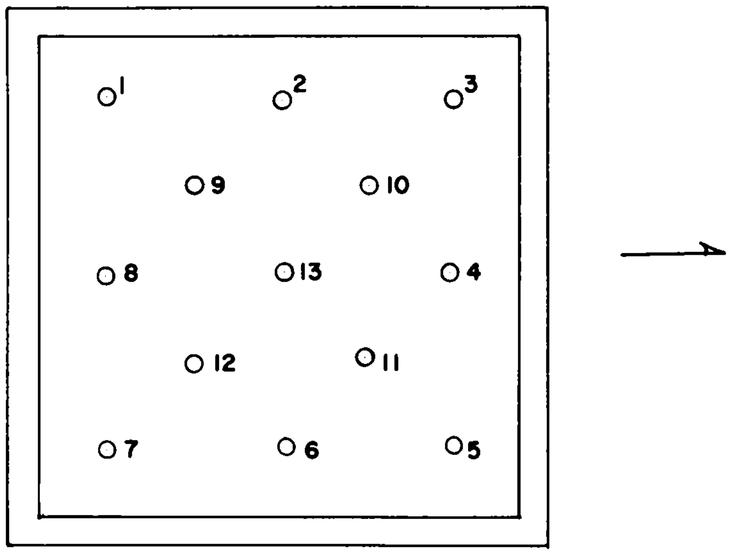

Fig. 2.6—Portable survey instrument layout (inside). Refer to App. A for additional sample identification.

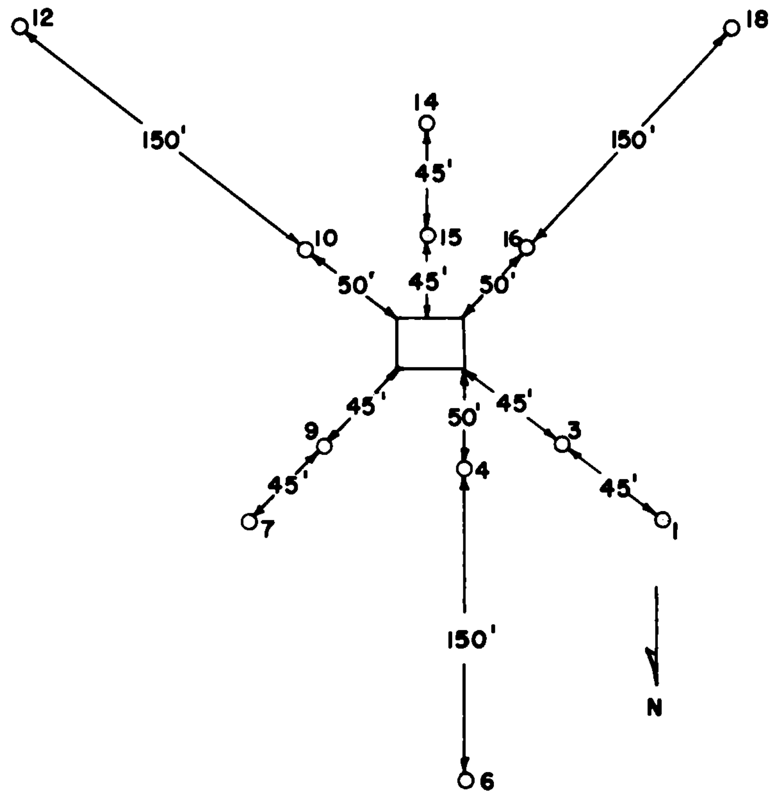

Fig. 2.7—Portable instrument layout (outside). Refer to App. A for additional sample identification.

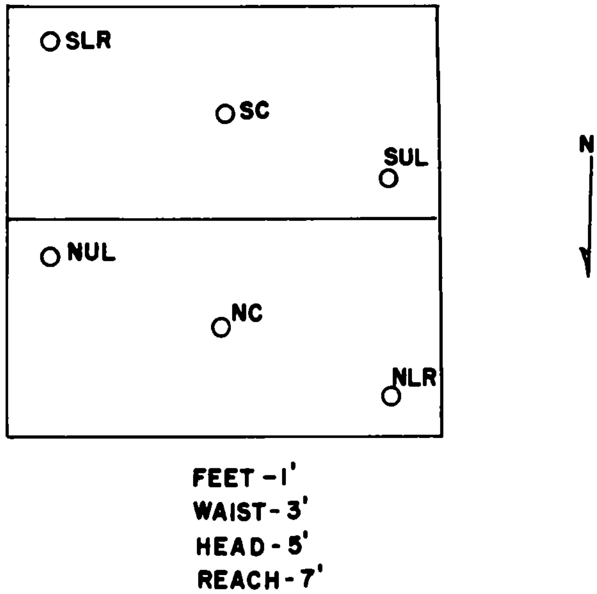

Fig. 2.8—Portable survey instrument layout (roof). Refer to App. A for additional sample identification.

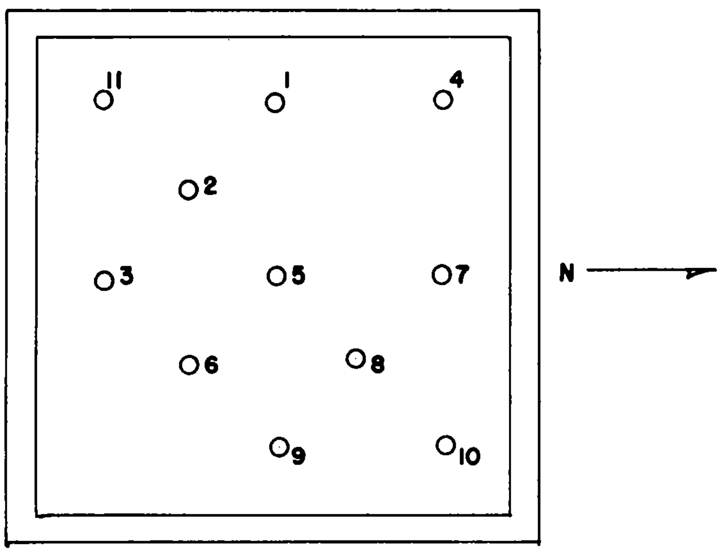

Fig. 2.9—Film-string layout. Refer to App. B for additional sample identification.

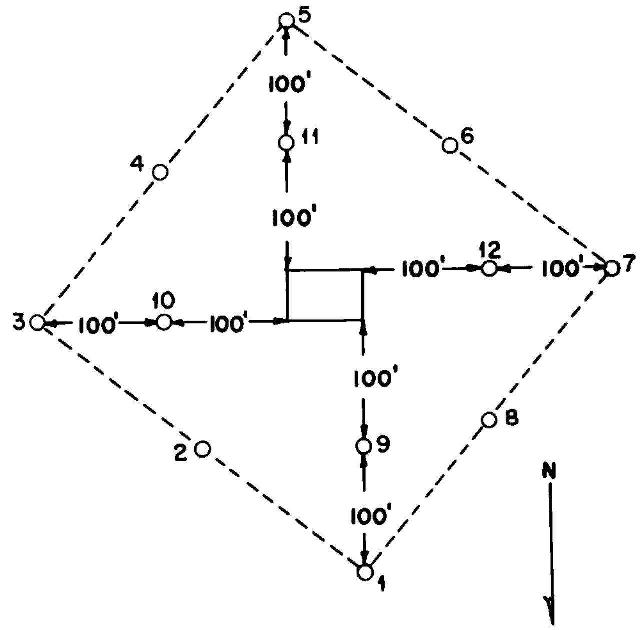

Fig. 2.10—Gummed-film-tray layout (outside). Refer to App. C for additional sample identification.

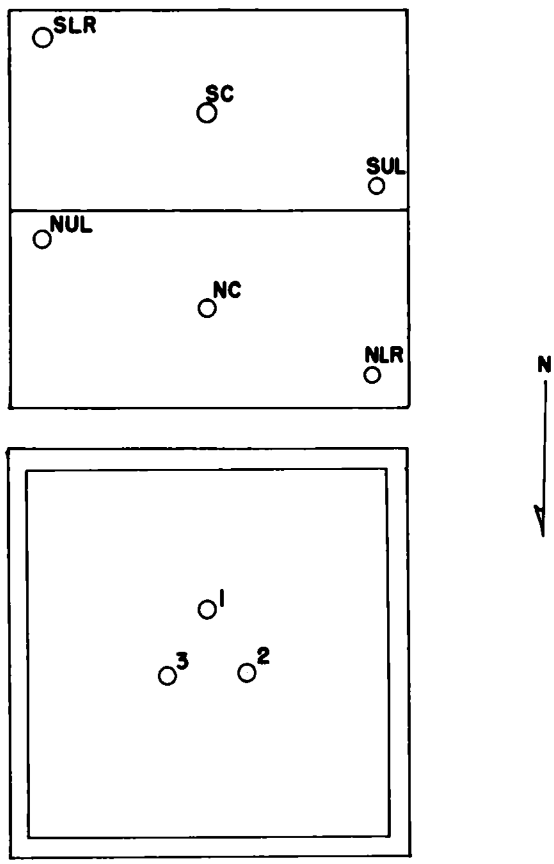

Fig. 2.11—Gummed-film-tray layouts (roof and inside). Refer to App. C for additional sample identification.

aluminum pedestals. For the roof position the frames were fastened to the plywood roof surface with nails.

The gummed films were positioned on D-1 and collected during the second recovery mission following fallout. Upon recovery, the films were taken to the Project 32.1 quonset hut at Camp Mercury for beta counting using end-window G-M counters 1.5 mg/cm^2 thick. Small circles were cut from the gummed-film sheets and mounted on plastic frames and disks for counting in the laboratory equipment. The mounted samples were counted sequentially at approximately daily intervals at Camp Mercury for about one week and then sent to HASL where the counting was continued at intervals of about two weeks. The gummed film sheets from which the circles were cut were also sent to HASL, where, after a delay allowing for sufficient decay to reduce the likelihood of contaminating equipment, the sheets were individually ashed in a muffle and the residue mounted in plastic dishes and counted.

A $\frac{1}{4}$-in.-thick plywood panel 2 by 2 ft square was nailed to the roof adjacent to each gummed-film frame at the same time that the gummed film was mounted. These plywood sample panels were recovered simultaneously with the gummed-film samples. The plywood was thought to be more representative of the deposition remaining on the roof surface at the time of decontamination than the gummed-film sample which would probably retain a greater proportion of the initial fallout deposit. The plywood squares were covered with gummed film placed sticky side down immediately prior to removal to minimize loss of fallout contamination during handling.

Counting procedures followed for plywood samples were approximately the same as those for the gummed film, with the exception that a correction was applied to compensate for attenuation of beta particles through the gummed-film seal on the plywood. Squares 2 by 2 in. were cut in triplicate from each plywood panel and handled in the same manner as the mounted gummed-film samples.

2.3.4 Energy Determination

The evaluation of effective gamma energy to aid in the interpretation of gamma-intensity measurements was attempted by an absorption method. The procedure followed was to bury Lucite absorber columns containing film packs placed at 5 cm intervals for a total length of 20 cm. A cluster of five absorbers was buried in the center of the basement with one absorber in a vertical position and the other four absorbers inclined at 45° from the vertical, each pointing toward one wall of the structure. The ends of the columns were left exposed. Four additional absorbers were placed in vertical positions outside the structure several feet from each of the four walls. The films in the absorbers were exposed for periods equal to those of the film packs which were suspended in the structure and these were all processed at the same time.

2.3.5 Air-dust Concentration, Sequential Air Sampler

Two automatic sequential air samplers were used to measure air-dust concentrations outside the door of the structure and in the structure basement. The units were automatically triggered by a photoelectric device and collected eight 10-min filter-paper samples in sequence. The sampler was started when light from the burst actuated the photoelectric device. The samples were recovered during the first recovery mission following each event and taken to Camp Mercury for beta counting.

Chapter 3

RESULTS

This experiment was designed to provide data for comparison with results obtained from theoretical and empirical studies. Since there were differences in the experimental conditions encountered in shots Diablo and Shasta, it was expected that there would be differences in protection factors and the other reported results. This same situation would exist in a nuclear attack and should be considered typical. The differences in the experimental conditions and results and their probable explanations are discussed in Chap. 4.

The following measurements were used in determining the reported results:

1. Protection factor and roof and ground contribution to dose rates—portable survey instruments.
2. Fallout deposition—gummed film, plywood.
3. Air-dust concentration—sequential filter-paper samples.

Measurements considered unsuitable for use are:

1. Protection factor and roof and ground contribution to dose rate—Jordan instruments, film packets, certain portable survey instruments.
2. Gamma-radiation energy—Lucite absorber columns.

The unused measurements are included in the appendixes, and reasons for their rejection are discussed in Chap. 4.

3.1 PROTECTION FACTORS

Figures 3.1 and 3.2 show how the protection factor calculated from portable survey instrument measurements varied with height in the structure, at the center and in the corners, for shots Diablo and Shasta, respectively, at the time of roof removal. As had been expected, the protection factor decreased with height, with greater differences near the walls than in the center of the building. The maximum protection factors immediately prior to roof removal were determined to be 24 in shot Diablo and 74 in shot Shasta. These maximum values were found in the corners of the basement 1 ft from the ground. Protection factors at each position of measurement both before and after roof removal for each shot are listed in Table 3.1.

In examining Figs. 3.2, 3.3, 3.6, and 3.7, it should be noted that in the Shasta event the estimated amount of fallout on the roof at the time of roof removal was only about one-tenth of that on the ground (see Sec. 3.3).

The protection factors at selected locations in shot Shasta varied with time after the shot as shown in Fig. 3.3. Similar information from shot Diablo is not presented because of inaccuracies which are discussed in Sec. 4.2.1.

The individual dose rates measured with portable survey instruments and used to calculate the protection factors are summarized in Appendix A. Free field dose rates were computed by averaging individual 3-ft dose-rate measurements for each time of interest.

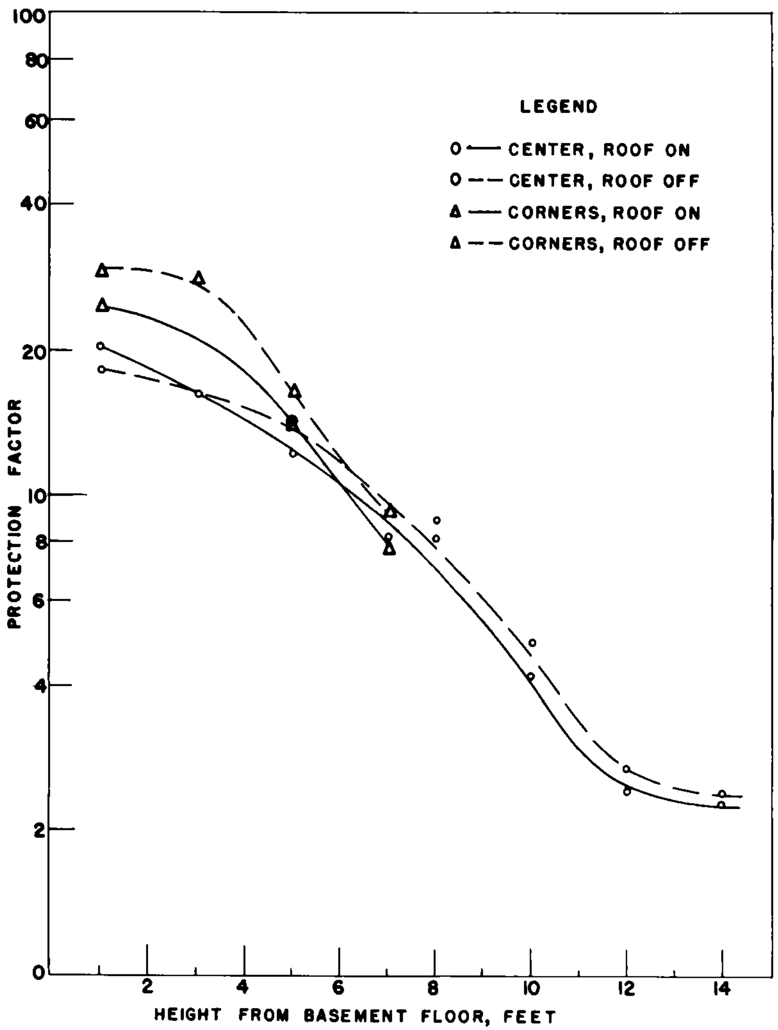

Fig. 3.1—Protection factors vs. height from basement floor at center and corners of structure (Diablo, H + 29.5 to 30.2 hr).

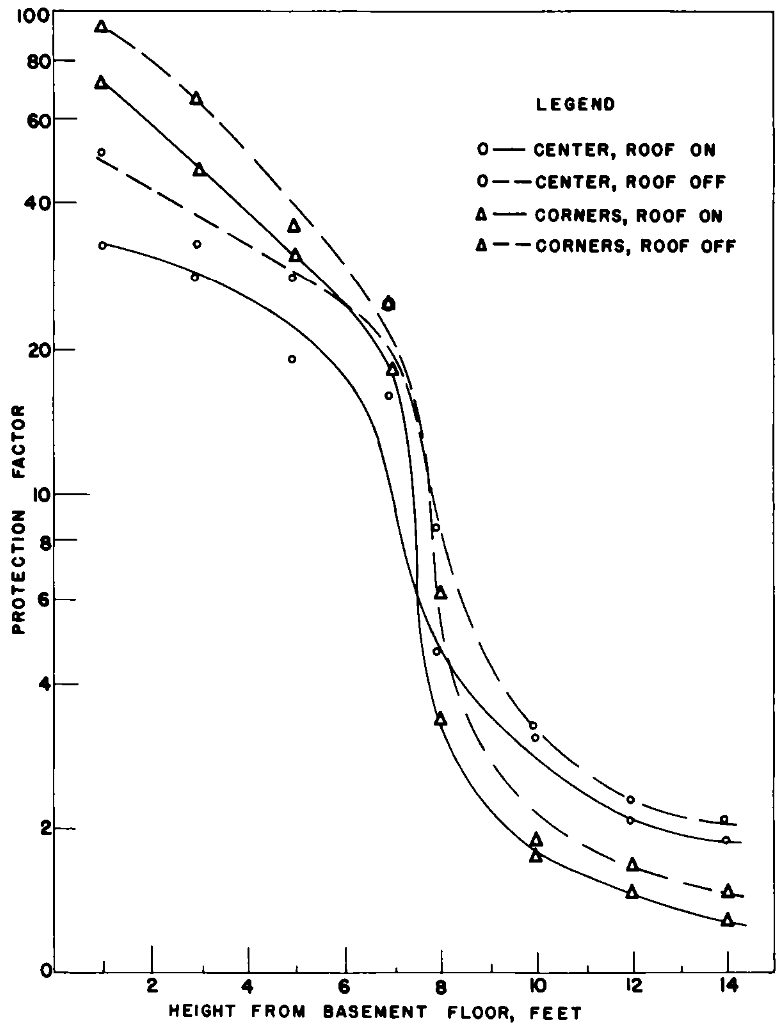

Fig. 3.2—Protection factors vs. height from basement floor at center and corners of structure (Shasta, H + 78.5 to 80.3 hr).

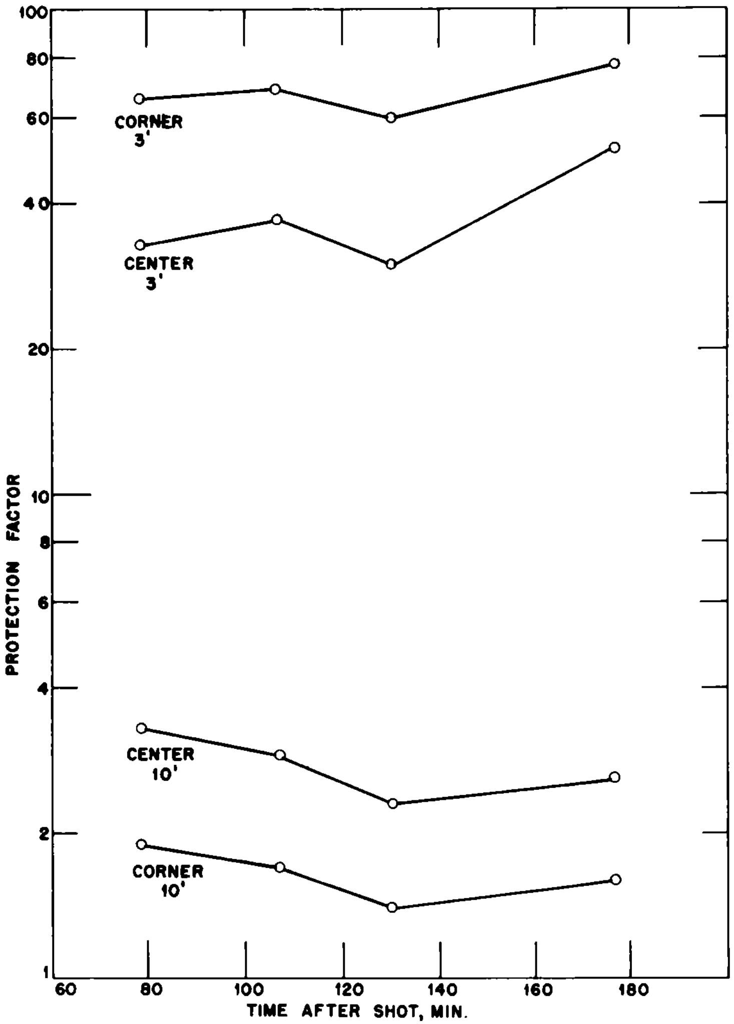

Fig. 3.3—Protection factors at selected locations in the structure vs. time after the shot (Shasta).

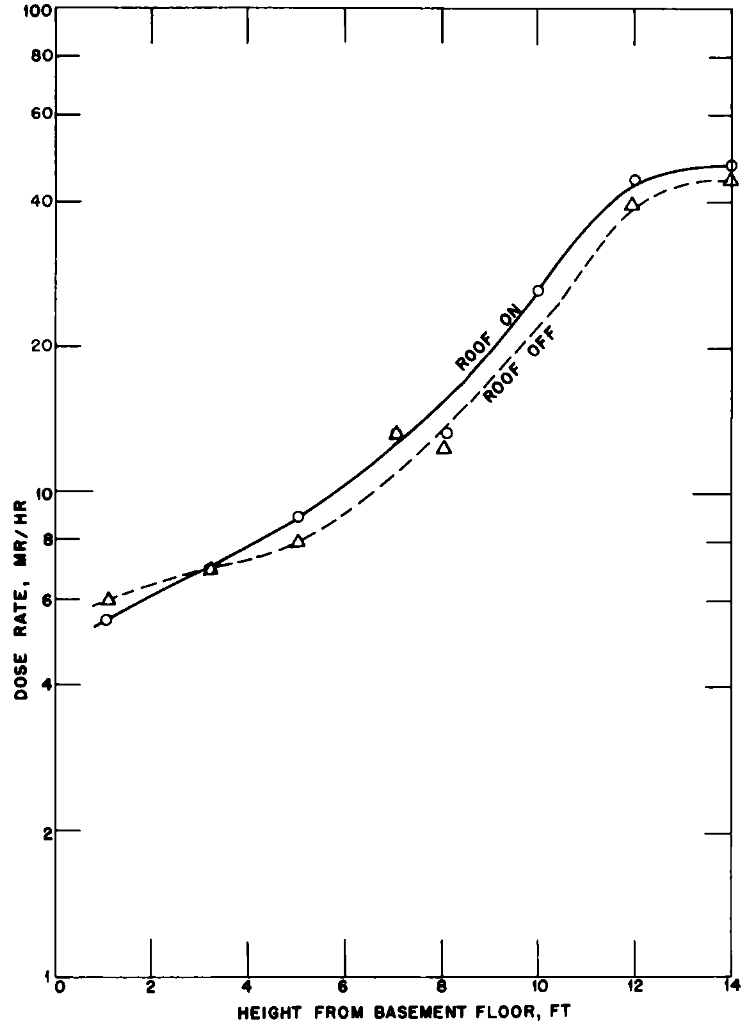

Fig. 3.4—Dose rates from ground contribution and ground-plus-roof contribution at center of structure (Diablo, H + 29.5 to 30.2 hr).

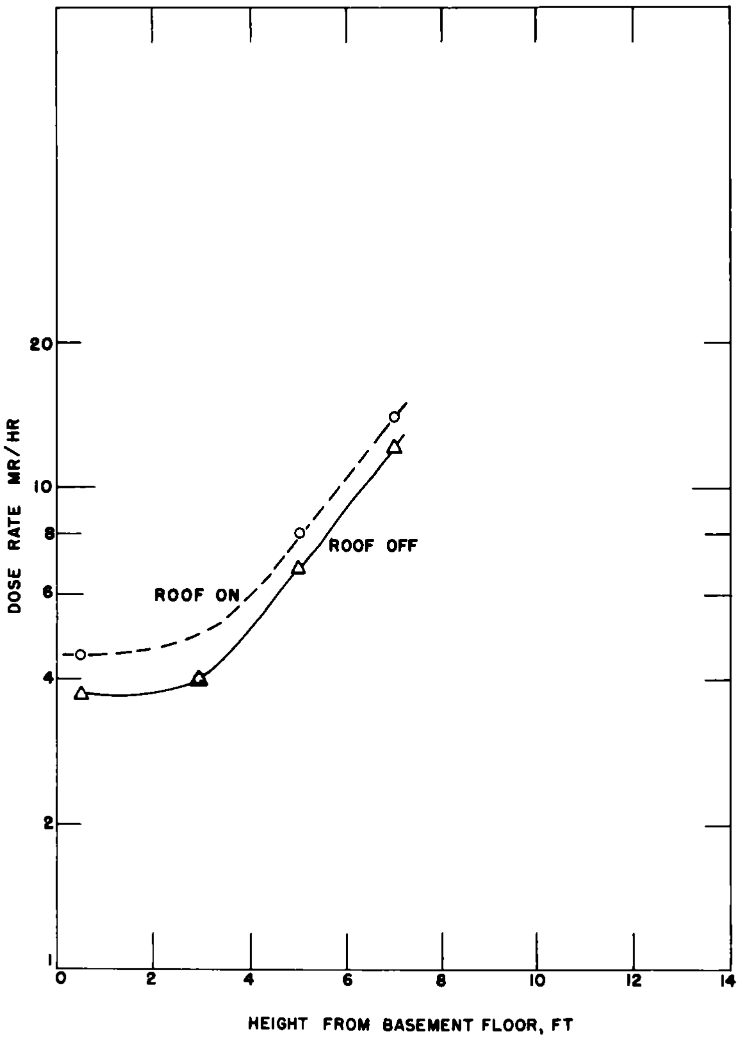

Fig. 3.5—Dose rates from ground contribution and ground-plus-roof contribution at corner positions in structure (Diablo, H + 29.5 to 30.2 hr).

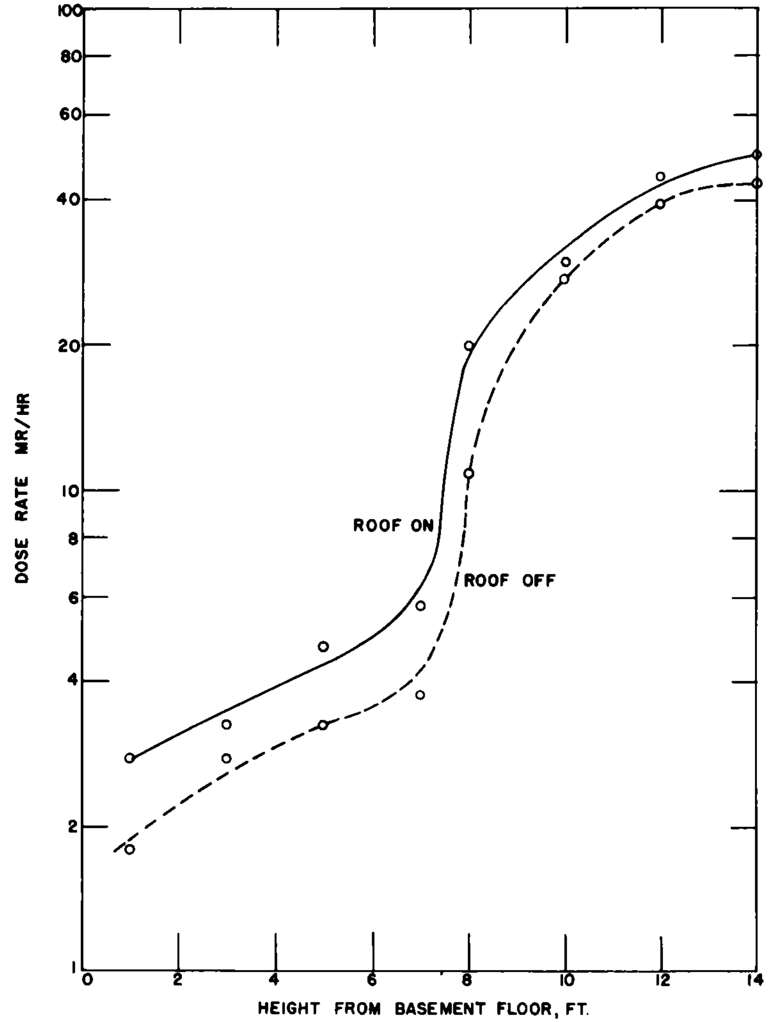

Fig. 3.6—Dose rates from ground contribution and ground plus roof contribution at center of structure (Shasta, H + 77.5 to 80.3 hr).

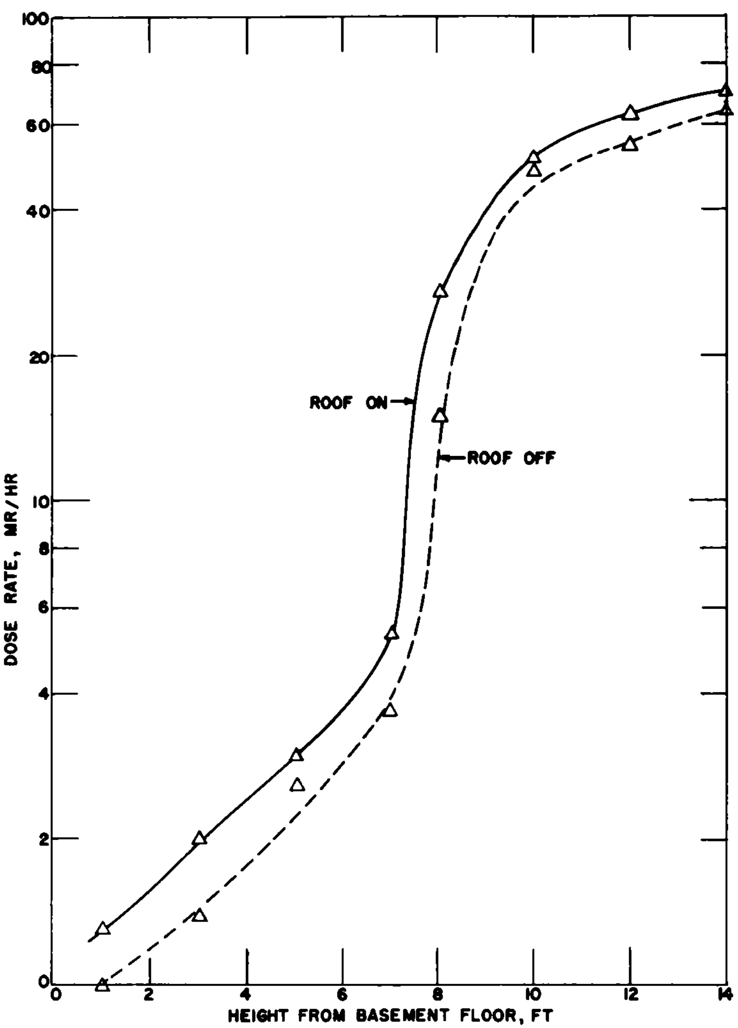

Fig. 3.7—Dose rates from ground-plus-roof contribution at corner positions in structure (Shasta, H + 77.5 to 80.3 hr).

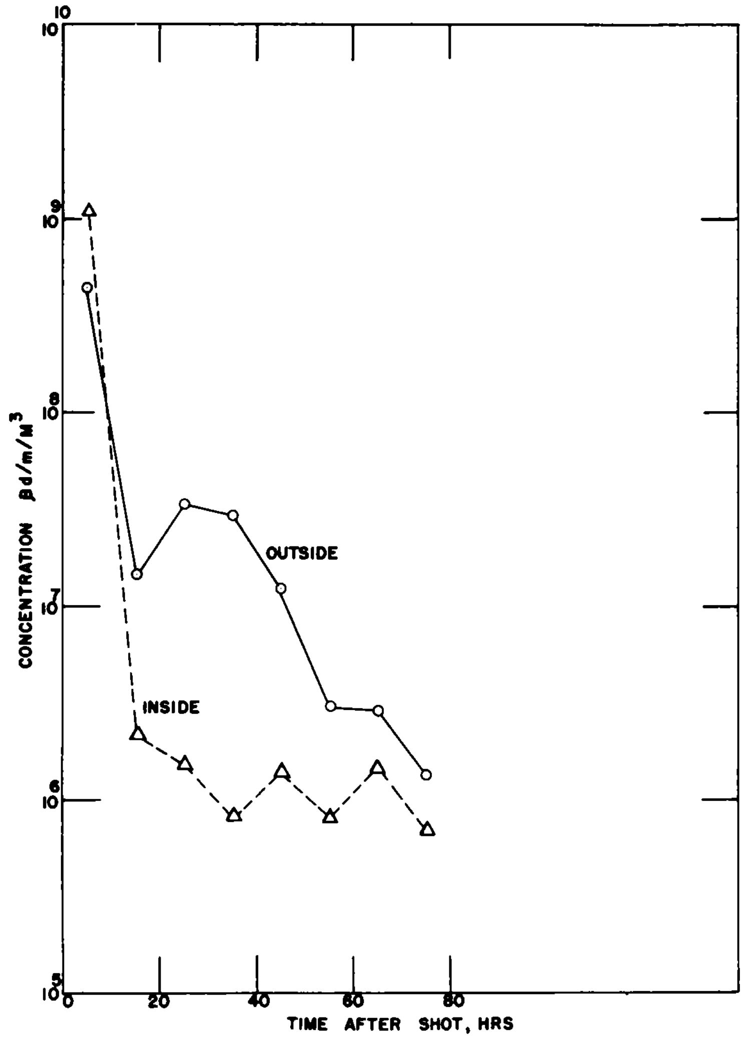

Fig. 3.8—Air-dust concentrations at times of collection (Diablo).

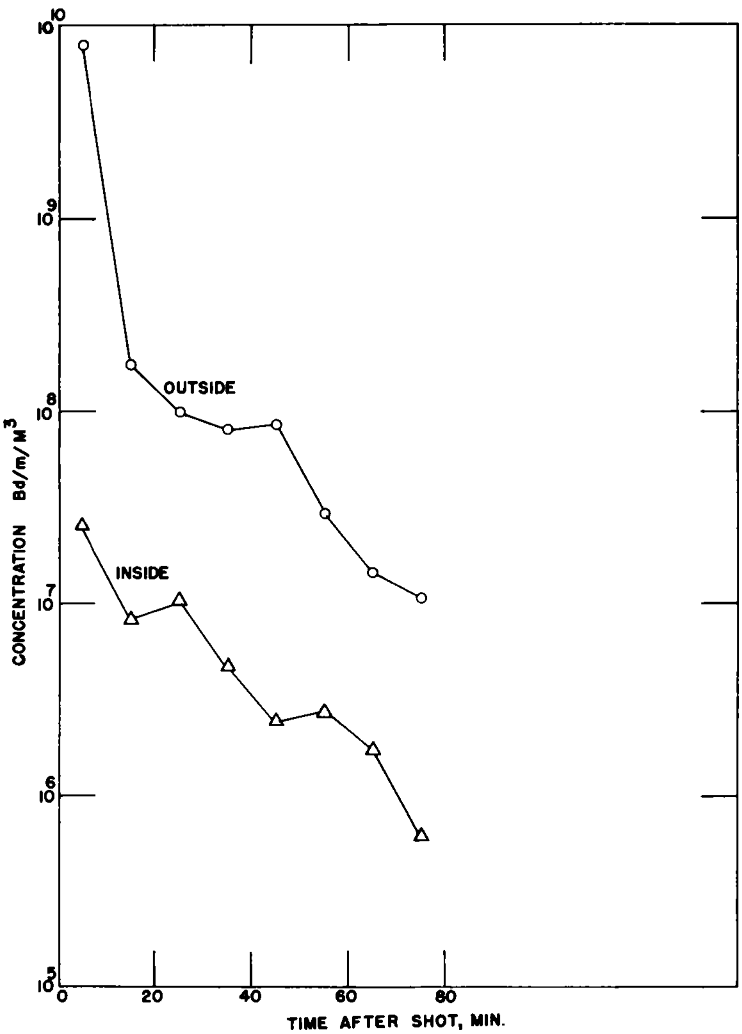

Fig. 3.9—Air-dust concentrations at times of collection (Shasta).

TABLE 3.1—SUMMARY OF PROTECTION FACTOR DETERMINATIONS

	Height, ft	Position 1	2	3	4	5	6	7	8	9	10	11	12	13
							Shot Diablo							
H + 29.5	1	24.5	18.3	24.5	24.5	24.5	24.5	24.5	24.5	20.0	24.5	20.0	24.5	20.0
(Roof on)	3	24.5	20.0	24.5	24.5	31.4	24.5	31.4	24.5	20.0	20.0	20.0	24.5	15.7
	5	13.8	12.2	12.2	11.0	13.8	12.2	15.7	12.2	12.2	11.0	12.2	11.0	12.2
	7	7.3	6.9	6.5	6.5	8.2	8.2	10.0	8.2	8.2	8.2	8.8	8.2	8.2
	8													8.2
	10													4.2
	12													2.4
	14													2.3
H + 30.16	1	31.4	24.5	31.4	24.5	24.5	24.5	31.4	24.5	24.5	24.5	20.0	20.0	18.3
(Roof off)	3	24.5	24.5	31.4	24.5	24.5	24.5	31.4	24.5	20.0	20.0	16.9	20.0	15.7
	5	15.7	15.7	13.8	13.8	18.3	13.8	18.3	15.7	13.8	13.8	12.2	15.7	13.8
	7	8.8	8.8	8.2	8.2	8.8	9.6	11.0	10.0	8.2	8.8	8.8	9.6	8.2
	8													8.8
	10													4.9
	12													2.7
	14													2.4
							Shot Shasta							
H + 77.8	1	66.5	71.6	77.5	66.5	66.5	62.0	77.5	54.7	40.4	51.7	51.7	54.7	33.2
(Roof on)	3	71.6	51.7	33.2	51.7	40.4	51.7	54.7	33.2	33.2	33.2	51.7	33.2	28.2
	5	51.7	19.4	24.5	24.5	28.2	24.5	28.2	24.5	24.5	24.5	24.5	24.5	19.4
	7	16.0	16.0	16.0	16.0	19.4	19.4	19.4	19.4	16.0	16.0	19.4	19.4	16.0
	8	2.3		3.1		4.7		5.1						4.7
	10	1.6		2.0		1.9		2.0						3.1
	12	1.3		1.6		1.9		1.3						2.1
	14	1.3		1.3		1.6		1.2						1.9
H + 80.4	1	66.5	85.5	100	66.5	100	77.5	100	93	62.0	62.0	77.5	71.6	51.7
(Roof off)	3	66.5	62.0	66.5	33.2	62.0	54.7	66.5	58.1	33.2	40.4	33.2	54.7	33.2
	5	33.2	33.2	33.2	24.5	33.2	33.2	51.7	33.2	28.2	28.2	28.2	24.5	28.2
	7	21.6	19.4	24.5	19.4	24.5	24.5	33.2	24.5	19.4	19.4	24.5	24.5	24.5
	8	6.2		4.7		9.3		6.2						8.5
	10	2.1		1.9		1.9		2.1						3.3
	12	1.7		1.7		1.6		2.1						2.3
	14	1.4		1.6		1.4		1.4						2.1

TABLE 3.2—SHOT SHASTA FALLOUT DEPOSITION

	Ground	Roof (gummed film)	Roof (wood)	Basement
Fallout deposition β, dis/min/sq ft	1.09×10^9	1.34×10^9	1.10×10^8	8.5×10^5
Number of samples constituting average	12	7	5	3

3.2 ROOF AND GROUND CONTRIBUTION TO DOSE RATE

Figures 3.4 through 3.7 show the dose rates inside the structure with the roof removed and just prior to roof removal in both the Diablo and Shasta events.

The difference between the two dose-rate curves represents the roof contribution to the total dose rate.

3.3 FALLOUT DEPOSITION

Average deposition in shot Shasta at the time of roof removal (H + 78.5) was determined to be as shown in Table 3.2.

The decay of gummed-film samples selected for a protracted study was very close to the $t^{-1.2}$ law up to about 200 days, after which the activity decreased more rapidly with time.

It was not possible to determine the amount of fallout deposition in shot Diablo because the residual gummed-film samples were not analyzed (see Sec. 4.2.3).

Fallout deposition measurements are summarized in Appendix C.

3.4 AIR-DUST CONCENTRATION

Figures 3.8 and 3.9 show the inside and outside dust concentrations at the time of sampling for both the Diablo and Shasta shots. The sample concentrations are plotted at the midpoints of the sampling periods.

The outside and inside values differ by approximately one order to magnitude, although there is considerable variability in the outside to inside ratios among the shot Diablo values.

Chapter 4

DISCUSSION

4.1 DATA RELIABILITY

Although the experiment was simplified as much as possible to eliminate or limit the effects of variables, there were many variables beyond control. The uncontrolled variables and their effect on the data and results are described in the discussion on data reliability that follows.

4.1.1 Dose-rate Measurements

It was planned to use the Jordan remote monitoring system as the basic source of data because it afforded continuous measurement and required a minimum of effort. The portable survey instruments and other devices were to be used for the collection of supplementary confirming data, but the portable survey instruments proved to be well suited for the experiment, and measurements made with these instruments appear to be the most reliable.

However, consideration must be given to two factors in interpreting the portable survey instrument measurements. These are:

1. Both ionization chamber type (Juno) and G-M type (2610) instruments were used in all shot Shasta recoveries and in one shot Diablo recovery but not for measurements in the same positions. In one shot Diablo recovery, measurements were made with both instruments at three above-grade locations with nearly identical corrected values at each location. A comparison of instrument readings at positions below grade as well as above (because of probable differences in gamma energy) would have added confidence to the data, but this was not done. (For gamma-radiation energy of 0.4 Mev, the G-M instrument response is about two-thirds of the actual dose rate. At lower energies, greater differences exist. Ionization chamber instruments, on the other hand, are relatively insensitive to changes in energy down to 0.2 Mev or less.[13]) However, the comparison which was made above grade with Juno and 2610 instruments indicates that energy dependence was an insignificant factor.

   Measurements in shot Diablo were made both above and below grade with Juno instruments (except for the last recovery), whereas measurements in shot Shasta were made above grade with Juno instruments and below grade with 2610 instruments.

2. Most below-grade and a few above-grade shot Diablo measurements were less than 10 mr/hr on Juno instruments and were subject to errors discussed in Sec. 4.2.1.

The following factors led to inaccuracies that may have adversely influenced the reliability of the Jordan instrument measurements:

1. Electronic drift
2. Inability to check calibration during each experiment
3. Generator power failure
4. Malfunction of recorders

Summaries of dose-rate measurements obtained from the Jordan and portable survey instruments are included in Appendix A. The data used for calculation of the desired results are based on the portable survey instrument measurements only.

4.1.2 Integrated Dose Measurements

In spite of the large number of film-pack measurements, the results are not consistent among themselves or with the data obtained by other means. The control films displayed doses of 200 to 300 mr, which is of the same order of magnitude as most of the measured doses. Since all the control films were stored in the test structure during the entire film experimental period, it was not possible to apportion the control doses to the various periods of film exposure. Other influencing factors, but of lesser magnitude, might have been: (1) possible changes in average gamma energy or energy spectra over the period of time the films were exposed, and (2) the film packs may have been contaminated or affected by temperature. A summary of the dose measurements obtained from the film packs is presented in Appendix B.

4.1.3 Fallout-deposition Measurements

Determination of fallout activity by the conventional gummed-film technique supplemented by measurements made on plywood panels is thought to be fairly accurate, particularly the results from samples analyzed at HASL about 18 months after shot Shasta. The sample results were extrapolated back to the time of interest, according to a decay curve established by frequent counting of 13 samples during the 18-month period. Each of these 13 samples showed only slight variation from a $t^{-1.2}$ decay. A factor of 1.6 was applied to all outdoor gummed-film sample results to correct for the effects of weather.[14]

4.1.4 Gamma-energy Measurements

No meaningful results were obtained from the film packs in the Lucite absorber columns. The technique, good in theory, did not work in practice.

4.1.5 Air-dust Concentration Measurements

The sequential sampler operated according to plan and collected the 8 samples with an efficiency of greater than 90 per cent. The filters were well protected from direct fallout and hence were not considered to be contaminated. To determine the concentrations at the time of sampling, a $t^{-1.2}$ extrapolation was made from the counting time.

4.2 INTERPRETATION OF RESULTS

4.2.1 Protection Factors

The ratio of the free-field dose rate to the dose rate at a selected location inside a building is a definition of protection factor. It represents the amount of attenuation of gamma radiation that exists at that location. As had been expected, the greatest protection was found in the corners of the basement and the least protection was found in the corners nearest the roof.

During the period of H + 57 to H + 59 in the Shasta event, heavy precipitation occurred prior to roof removal (and the first complete measurements) and washed away much of the roof activity. Because of this, the amount of fallout on the roof for shot Shasta was determined to be only about one-tenth of that on the ground. The protection factors at positions near the roof would have been still less if roof-fallout activity were similar in quantity to ground-fallout activity.

An estimate of the relative amount of roof activity in the Diablo event could not be made since the appropriate samples were not counted. It can be presumed that there was relatively more activity in shot Diablo than Shasta because of the absence of precipitation in shot Diablo. The curves showing roof contribution to total dose rate bear this out, although in neither the Diablo nor Shasta events are the roof contributions different enough to notice significant effects on the protection factors. Examination of the plots of protection factors and dose rates

vs. height (at the time of roof removal) shows that the shot Diablo curves are much "flatter" than the shot Shasta curves. That is, in shot Shasta the protection factors in the basement were greater and those above grade were similar. In fact, one of the sets of shot Diablo roof-on and roof-off curves crossed at the lowest positions of measurement. It is believed that the reported differences are due to the choice of survey instruments for below-grade measurements and to the calibration of these instruments. In all the shot Diablo below-grade measurements, readings below 10 mr/hr were encountered. Some were as low as 1 to 2 mr/hr. Juno instruments (which were used here) cannot be interpreted at these very low levels with an accuracy of greater than 50 per cent, even under ideal conditions. Since the instrument calibrations did not include any points less than 10 mr/hr, interpretations of readings less than 10 mr/hr were accomplished by extrapolations of the calibration curves to lower dose rates. The overall effect may have resulted in errors of as much as 400 per cent. The nature of these effects would tend to make them additive rather than canceling.

There may have been more fallout in the basement in shot Diablo than in Shasta since the detonation in shot Diablo blew the door off, thereby increasing infiltration. This condition would also cause the protection factor curve to "flatten." In addition, a fallout gradient on the ground was known to exist in shot Diablo but not in shot Shasta (Fig. 4.1).

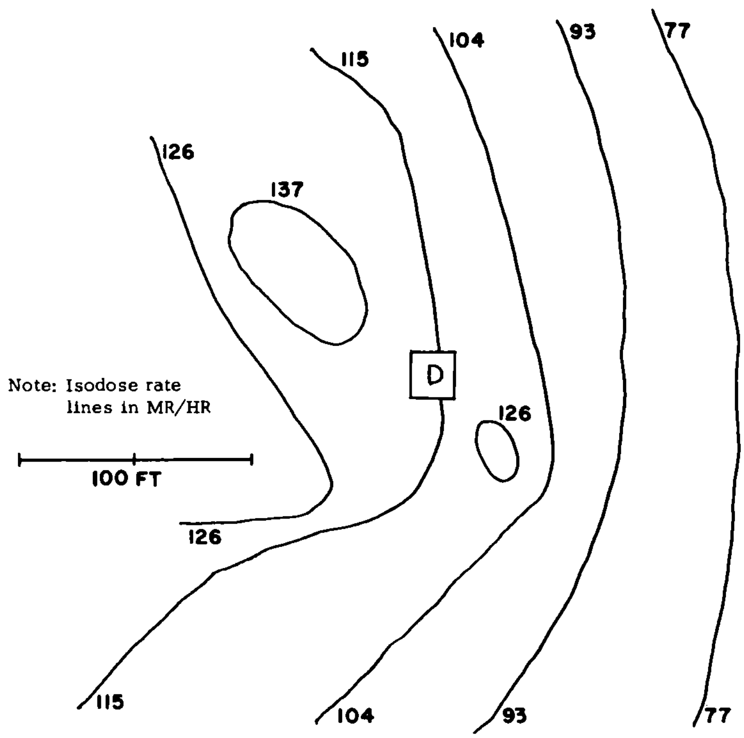

Fig. 4.1—Fallout distribution around structure (Diablo, H + 29.5 hr).

The plot of protection factor vs. time after the shot for any particular location in the structure is straightforward. In the Shasta event there does not appear to be significant change with time. In the Diablo event wide fluctuations exist. It is believed that these fluctuations are the result of the use of the Juno survey instruments, as discussed in the previous paragraph, and not actual changes of protection factors with time.

Since fallout occurred within the building through infiltration in shots Shasta and Diablo, it was necessary to determine whether such fallout contributed to the dose rates measured within the building. The ratio of outside dose rate to outside fallout activity was applied to the inside fallout activity with a correction factor for the noninfinite area of the basement.[15]

The dose rate from basement fallout in shot Shasta at the time of roof removal calculated by this method was 0.03 mr/hr at 3 ft from the basement floor. Since the measured dose rates of interest were all over 1.0 mr/hr, no data corrections were made to account for this minor effect.

The most significant disturbance of the idealized protection factors that this experiment was designed to measure was caused by the structural shielding of the building. This effect is the most difficult to evaluate quantitatively, since the building side walls, end walls, and roof are all of different construction and the supporting columns are I-beams with increasing web length from grade to eaves. The best information obtainable from an experiment that was performed to evaluate the effect of the structural shielding was an estimate of 25 per cent as a typical attenuation value for a position in the center of the building. The protection factors determined in both the Diablo and Shasta events were not adjusted to compensate for structural attenuation. An adjustment would have the effect of reducing the experimentally measured protection factors.

The protection factors determined in this experiment at two specific locations are compared in Tables 4.1 and 4.2 with those determined from charts[16] developed by the NBS for

TABLE 4.1 — PROTECTION FACTOR COMPARISONS*

	Shot Diablo (Corrected for wall attenuation)	Shot Shasta (Corrected for wall attenuation)	OCDM	Shot Diablo (Not corrected for wall attenuation)	Shot Shasta (Not corrected for wall attenuation)	EG&G
Roof on	13.2	22.1	23	18	31	18.8
Roof off	12.7	31.3	28.6	17	43	26.8

* Two feet above basement floor, center of structure.

TABLE 4.2 — PROTECTION FACTOR COMPARISONS*

	Shot Diablo (Corrected for wall attenuation)	Shot Shasta (Corrected for wall attenuation)	OCDM	Shot Diablo (Not corrected for wall attenuation)	Shot Shasta (Not corrected for wall attenuation)	EG&G
Roof on	3.12	2.18	1.72	4.2	2.95	1.39
Roof off	3.6	2.49	1.75	4.8	3.3	1.46

* Three feet above grade, center of structure.

OCDM and experimentally from moving point source measurements[17] by Edgerton, Germeshausen, and Grier (EG&G). The OCDM values should logically be compared with the Project 32.1 values corrected for wall attenuation while the EG&G values should be compared with the uncorrected Project 32.1 values since the EG&G measurements were obtained using the same structure that was used for Project 32.1. (The values reported by EG&G are in mr/hr/mc/ft^2 and were converted to units similar to those used in this report.[1])

4.2.2 Ground and Roof Contributions

The plots in Figs. 3.5, 3.6, and 3.7 showing the dose rates both with and without roof contribution exhibit small but distinct differences which are the roof contribution alone. In the Shasta event the roof contribution is caused by only about one-tenth of the activity per unit area of that on the ground. Since the roof and ground activities are unknown in the Diablo event, a comparison between shot Diablo data and shot Shasta data cannot be made.

4.2.3 Fallout Deposition

Small portions of the gummed-film and plywood samples cut out in the field were counted periodically for several weeks after each shot. These cut-out portions, together with the remaining samples (in shot Shasta only) were counted at HASL about 18 months later. The activities from all parts of each original sample were totalled and extrapolated back to the

time of interest according to a curve following the decay of selected samples.

The amount of fallout deposition on the ground was similar to that on the roof according to the gummed-film measurements. As expected, roof fallout on the plywood samples was less (about one-tenth of that on the gummed film), principally because of weather effects.

Chapter 5

CONCLUSIONS

5.1 CONCLUSIONS

Although field experiments like the one reported here are characterized by many inherent and uncontrolled limitations, results obtained, such as for protection factors, roof and ground contributions to dose rates, fallout deposition, and air-dust concentrations can be used as basic experimental data by workers in the field of fallout protection.

The reported values, although they represent the situation in an actual nonideal structure, are remarkably similar to values obtained by other measurements and calculations in ideal structures. Better control of some of the experimental variables and proper functioning of equipment would have resulted in more reliable, accurate results.

5.2 RECOMMENDATIONS

If the type of information developed from these experiments is found to be useful, improvements recommended below should be made in further experimentation to increase the value of the results and facilitate the collection of data.

1. Complete sets of data from several shots should be obtained so that normalized results can be determined.
2. The test structure itself should be simplified to eliminate complex attenuation properties. A structure of uniform wall thickness and composition would be preferable to the type employed in this study.
3. The surrounding ground area should be leveled and smoothed as much as possible to reduce the effects of gross surface irregularities.
4. The test structure should be sufficiently sealed to prevent the entry of fallout.
5. If unattended electrical equipment is to be used, a completely reliable power source should be available. The use of a field generator should be avoided.
6. Provisions should be made for obtaining field measurements of the effective gamma energy of fallout.

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Appendix A

DOSE-RATE MEASUREMENTS

TABLE A.1 — SUMMARY OF DOSE RATE MEASUREMENTS,* PORTABLE SURVEY INSTRUMENTS

		Shot Diablo — Gamma dose rate, mr/hr — Position																																
		Outside																		Inside														
Time	Height	1	NBS NW	3	4	J13	6	7	NBS NE	9	10	J14	12	14	NBS S	15	16	J15	18	1	2	3	4	5	6	7	8	9	10	11	12	13		
H + 29.5	1																			4.5	6.0	4.5	4.5	4.5	4.5	4.5	4.5	5.5	4.5	5.5	4.5	5.5		
(roof on)	3	93	77	126	115	104	98	115	115	126	137	137	126	115	104	115	104	93	77	4.5	5.5	4.5	4.5	3.5	4.5	3.5	4.5	5.5	5.5	5.5	4.5	7.0		
	5	82	77	104	104	93	93	104	115	109	126	126	121	104	98	104	93	88	71	8.0	9.0	9.0	10	8.0	9.0	7.0	9.0	9.0	10	9.0	10	9.0		
	7	82	77	98	104	93	93	104	115	104	126	126	121	104	98	104	93	88	77	15	16	17	17	13.5	13.5	11	13.5	13.5	13.5	12.5	13.5	13.5		
	8																															13.5		
	10																															26.5		
	12																															45		
	14																															48		
H + 30.16	1	Outside readings unchanged from H + 29.5																		3.5	4.5	3.5	4.5	4.5	4.5	3.5	4.5	4.5	4.5	5.5	5.5	6.0		
(roof off)	3																			4.5	4.5	3.5	4.5	4.5	4.5	3.5	4.5	5.5	5.5	6.5	5.5	7.0		
	5																			7.0	7.0	8.0	8.0	6.0	8.0	6.0	7.0	8.0	8.0	9.0	7.0	8.0		
	7																			12.5	12.5	13.5	13.5	12.5	11.5	10	11	13.5	12.5	12.5	11.5	13.5		
	8																															12.5		
	10																															22.5		
	12																															40.5		
	14																															45		
H + 54.5	1																			4.0		4.5		3.5								5.5		
	3		33			41			45			45			41			36.5														6.0		
	5																															6.0		
	7																																	
	8																			8.0		6.0				6.5						10		
	10																			23		18.5				25						14		
	12																			25		24				26						13.5		
	14																			25		24				26						23		
H + 107.5	1																			4.5		5.0		4.5		5.0						5.5		
	3		17			21.5			22.5			25			20.5			17.5		5.0		5.0		4.5		5.5						5.8		
	5																			5.5		5.0		5.0		5.5						6.0		
	7																															7.0		
	8																			9.0		8.0		10		8						9.0		
	10																			14		15		17		16						11		
	12																			14		15		17		16								
	14																																	
H + 128.5	1																			0.2		0.4		0.15				0.55	0.6	0.35	0.3	0.8		
	3		11.5			14.5			17			18.5			14.5			13		0.4		0.5		0.25				0.7	0.7	0.55	0.5	1.0		
	5																			0.5		0.6		0.4				0.8	1.25	0.95	0.95	1.2		
	7																																	
	8																			4.0		3.0		3.0		2.0						2.0	1.8	
	10																			9.0		9.0		11		9.0						4.0	4.2	2610
	12																			10		9.0		11		9.5						5.5	5.3	
	14																																	

*Outside and above-grade inside measurements made with Juno instruments; below-grade inside measurements made with 2610 instruments.

Table A.1 — (Continued)

Shot Shasta

Gamma dose rate, mr/hr — Position — Outside

Time	Height	1	NBS NW	3	4	J13	6	7	NBS NE	9	10	J14	12	14	NBS S	15	16	J15	18
H + 77.8	1	100	100	110	40	80	70	110	80	105	110	110	100	115	100	120	125	120	115
(roof on)	3	90	90	100	70	70	65	100	70	100	100	100	100	100	100	100	105	100	105
	5	90	90	95	70	50	70	90	80	100	90	100	90	100	100	90	100	100	100
	7	90	90	95	75	50	70	90	75	100	100	100	100	100	100	100	105	100	100
	8																		
	10																		
	12																		
	14																		
H + 80.4	1	Outside readings unchanged from H + 77.8																	
(roof off)	3																		
	5																		
	7																		
	8																		
	10																		
	12																		
	14																		
H + 106.5	1	65	60	70	60	60	58	60	40	70	80	92	55	55	65	60	75	65	55
	3	50	50	70	58	50	52	55	40	60	55	55	50	55	60	50	70	51	55
	5	42	47	52	52	50	47	52	42	58	47	47	47	47	52	47	52	47	52
	7	47	47	52	52	50	47	50	40	52	47	52	47	47	52	47	63	47	52
	8																		
	10																		
	12																		
	14																		
H + 129.3	1	40	40	40	50	40	45	40	25	50	50	60	45	40	45	45	50	40	55
	3	40	40	40	28	30	40	35	25	40	35	40	45	35	35	35	40	40	35
	5	37	37	37	32	26	37	32	26	37	32	42	42	32	32	32	42	37	37
	7	37	37	37	32		37	32	32	37		47	42	37	32	32	57	47	42
	8																		
	10																		
	12																		
	14																		
H + 176.8	1	30	35	35	40	40	30	35	35	40	30	40	20	25	45	30	45	45	40
	3	30	30	30	30	35	30	35	30	40	40	20	20	25	35	20	40	45	30
	5	30	30	30	35	25	30	35	30	35	30	20	20	20	30	20	35	45	30
	7	35	35	40	35	30	30	40	35	45	30	20	20	30	50	35	40	40	35
	8																		
	10																		
	12																		
	14																		

Gamma dose rate, mr/hr — Position — Inside

Time	Height	1	2	3	4	5	6	7	8	9	10	11	12	13
H + 77.8	1	1.4	1.3	1.2	1.4	1.4	1.5	1.2	1.7	2.3	1.8	1.8	1.7	2.8
(roof on)	3	1.3	1.8	2.8	1.8	2.3	1.8	1.7	2.8	2.8	2.8	1.8	2.8	3.3
	5	1.8	4.8	3.8	3.8	3.3	3.8	3.3	3.8	3.8	3.8	3.8	3.8	4.8
	7	5.8	5.8	5.8	5.8	4.8	4.8	4.8	4.8	5.8	5.8	4.8	4.8	5.8
	8	40		30		20		18						20
	10	60		47		50		46						30
	12	70		60		50		70						45
	14	70		70		60		80						50
H + 80.4	1	1.4	1.1	0.9	1.4	0.9	1.2	0.9	1.0	1.5	1.5	1.2	1.3	1.8
(roof off)	3	1.4	1.5	1.4	2.8	1.5	1.7	1.4	1.6	2.8	2.3	2.8	1.7	2.8
	5	2.8	2.8	2.8	3.8	2.8	2.8	1.8	2.8	3.3	3.3	3.3	3.8	3.3
	7	4.3	4.8	3.8	4.8	3.8	3.8	2.8	3.8	4.8	4.8	3.8	3.8	3.8
	8	15		20		10		15						11
	10	45		50		50		45						28
	12	55		55		60		45						40
	14	65		60		65		65						44
H + 106.5	1	0.4	0.7	0.5		0.7	0.8	0.6	0.6	0.8	0.8	0.7	0.9	1.0
	3	0.7	0.9	0.9	1.7	0.8	1.1	0.8	1.2	1.6	1.1	1.3	1.2	1.5
	5	1.5	1.5	1.5	1.8	1.6	1.7	1.4	1.6	1.8	1.6	1.6	1.6	2.6
	7	4.3	3.8	3.3	3.3	3.0	2.8	2.8	3.0	3.3	2.8	3.0	3.3	3.6
	8	13		15		11		10						9.0
	10	33		30		34		33						19
	12	36		32		36		34						25
	14	37		37		37		37						32
H + 129.3	1	0.4	0.7	0.3	0.6	0.4	0.5	0.4	0.5	0.6	0.7	0.6	0.6	0.8
	3	0.6	0.9	0.7	0.9	0.6	0.7	0.6	0.6	1.1	1.2	1.1	1.0	1.2
	5	1.2	1.2	0.9	1.3	1.1	0.9	0.9	1.2	1.5	1.6	1.4	1.4	1.4
	7	3.3	2.8	2.3	2.3	2.3	1.8	1.8	2.3	1.8	2.3	2.3	2.3	2.3
	8	9.0		10		8.0		8						7.0
	10	26		26		27.5		26						16
	12	26		23		25		24						17
	14	29		29		28		29						25
H + 176.8	1	0.2	0.3	0.2	0.4	0.3	0.4	0.3	0.3	0.4	0.5	0.3	0.3	0.5
	3	0.3	0.5	0.3	0.5	0.4	0.5	0.4	0.5	0.6	0.6	0.6	0.6	0.6
	5	0.6	0.8	0.7	0.9	0.7	0.6	0.6	0.6	0.7	0.9	0.9	0.8	0.8
	7	1.3	1.1	1.3	1.2	1.1	0.9	0.9	1.2	1.2	1.1	1.1	1.1	1.5
	8	10		15		9.0		9.0						6
	10	20		25		20		17						12
	12	22		25		22		22						17
	14	22		30		24		24						20

TABLE A.2—SUMMARY OF DOSE RATE MEASUREMENTS, JORDAN INSTRUMENTS

	Gamma dose rate, mr/hr														
	Inside												Outside		
Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
							Shot Diablo								
H + 5				70	19	680	510	18	68	490	330	380	350	290	420
H + 28				8.3	4.2	68	52	2.6	12						
H + 30				7.4	4.0	66	50	2.4	11	102	66	74	113	90	103
H + 54.5				3.0	2.1	30	20	1.2	4.0	50	32	35	51	84	60
H + 144				0.86	0.68	12	7.2	0.37	0.92	15	9.2	11	21	30	21
H + 168				0.70	0.50	6.9	5.6	0.29	0.61	13	7.7	9.4	17	26	17
							Shot Shasta								
H + 4.5	108	7800	3400	320	360	4000	5200	450	330	4800	7000	2350	2600	6000	10000^+
H + 5.1	76	7200	2550	250	320	7300	6400	400	310	4600	6200	2000	2450	5400	9500
H + 14.3	24	1750	700	58	77	1350	1200	86	66	1200	1300	570	650	1400	1800
H + 77.8	7.0	142	49	5.0	8.6	2200	84	6.2	11	106	100	135	87	135	165
H + 80.4	5.0	145	45	4.0	7.4	2500	87	4.6	6.6	106	103	90	87	139	178
H + 106.5	1.5	120	31	2.6	4.9	430	87	2.9	4.7	98	91	72	87	125	165
H + 130.3	1.1	92	25	2.2	3.6	450	74	2.2	3.6	77	73	60	64	95	135
H + 176.8	1.0	63	20	1.6	3.1	210	55	1.6	2.9	48	48	44	40	62	78

Appendix B

INTEGRATED DOSE MEASUREMENTS

TABLE B.1 —SUMMARY OF INTEGRATED DOSE MEASUREMENTS, FILM PACKS

		Gamma dose, mr													
		Height above basement floor, ft													
Position		1	2	3	4	5	6	7	8	9	10	11	12	13	14
							Shot Diablo								
H + 12	1	450	460	490	460	470	560	670	990	1057	1217	1377	1410	1470	
to	2	530	530	530	590	710	777	777	950	1123	1290	1590	1670	1710	
H + 30	3	550	540	550	580	610	710	730	1057	1410	1750	1750	1790	1890	
	4	470	470	450	580	590	580	580	1097	1390	1530	1750	1750	1750	
	5	330	310	360	444	500	630	803	730	850	923	923	1170	1270	
	6	500	500	404	500	560	620	670	740	870	1043	1230	1363	1410	
	7	470	444	460	444	460	480	670	937	1030	1190	1170	1170	1203	
	8				540	560	580	670	790	910	1003	1110	1150	1170	
	9	360	410		460	510	520	670	830	950	1070	1270	1350	1350	
	10	304	370	410	510	580	803	1170	1350	1770	1890	1910	1810	1710	
	11	390	390	390	437	500	600	710	1017	1330	1430	1750	1810	1670	
H + 30	1	85	50	60	50	55	60	165	290	390	540	590	660	650	
to	2	80	100	110	85	60	60	150	230	310	440	490	620	670	
H + 55	3	150	120	130	125	140	125	200	325	524	630	670	690	690	
	4	220	190	200	230	260	310	390	580	670	730	830	977	870	
	5	270	280	310	330	330	360	384	484	530	610	660	760	830	
	6		320	350	370	384	390	430	524	600	750	810	910	1370	
	7	310	260	260	230	280	290	310	490	630	710	810	910	930	
	8	220	190	165	350	270	270	310	350	400	477	590	650	680	
	9	165	165	165	190	215	215	250	320	400	540	600	660	670	
	10	200	165	180	200	250	310	450	700	870	1063	1097	1110	1130	
	11	230	250	250	260	200	320	377	610	830	857	1030	1043	1063	
							Shot Shasta								
H + 14.5	1	1280	1400	1380	1500	1600	1700	1900	2400	2960	3260	3810	3810	4060	3893
to	2	1380	1480	1360	1400	1400	1480	1720	2000	2400	2640	3110	3110	3810	3460
H + 77.5	3	1000	1067	1067	1100	1220	1380	1540	2040	2720	3410	3460	3560	3460	3560
	4	947	1120	1120	1160	1300	1440	1640	2200	2400	2720	3210	3110	3360	3110
	5	1500	1520	1520	1560	1680	1600	1640	1760	2040	2200	2400	2560	2640	2810
	6	1427	1540	1600	1720	1760	1760	1840	2100	2520	2810	3210	3360	3560	3460
	7	1040	1067	1027	1100	1260	1380	1413	1740	2280	2680	2860	2860	3110	3210
	8														
	9														
	10	947	980	1053	1173	1360	1520	1920	2480	2760	2910	3160	3210	3160	2910
	11	1220	1220	1160	1380	1320	1620	1920	2440	2720	2720	3110	3810	3360	2560
H + 77.5	1	520	550	587	680	733	840	907	1040	1280	1320	1440	1540	1560	1600
to	2	360	480	500	480	540	613	640	640	920	1040	1340	1440	1520	1620
H + 1775	3	330	380	330	420	540	550	550	773	980	1340	1480	1620	1560	1600
	4	410	340	330	420	480	600	760	920	1120	1427	1560	1580	1480	1640
	5														
	6	350	500	460	520	613	640	747	867	980	1053	1400	1040	1480	1480
	7	430	450	430	370	340	430	450	650	720	1027	1080	1173	1200	1300
	8	370	380	350	370	280	310	400	450	680	893	840	1140	1200	1067
	9	360	330	340	310	340	350	360	600	760	893	1000	1040	1140	1067
	10	160	270	270	270	300	450	560	760	920	933	1160	1140	1013	1067
	11	600	627	640	660	720	733	907	1000	1080	1300	1413	1380	1380	1440

Appendix C

FALLOUT—DEPOSITION MEASUREMENTS

SAMPLE IDENTIFICATION CODE

Digit	Designations
1	D - Diablo
	S - Shasta
2	G - Gummed film
	W - Wood
3	I - Inside
	O - Outside
	NUL - Roof, north upper left
	NC - Roof, north center
	NLR - Roof, north lower right
	SUL - Roof, south upper left
	SC - Roof, south center
	SLR - Roof, south lower right
4	1,2,3, ... - Outside or inside position
5	1,2,3, ... - Small samples cut from original samples

TABLE C.1 —SUMMARY OF FALLOUT DEPOSITION MEASUREMENTS

(Shot Diablo: beta activity, dis/min/sq ft)

Sample	D + 0.712	D + 0.726	D + 0.796	D + 1.20	D + 1.28	D + 1.50	D + 2.21	D + 2.26	D + 38	D + 39	D + 56	D + 115	D + 247	D + 540	D + 570
DGO1-1	7.38×10^{5}	7.08×10^{5}	6.48×10^{5}	4.02×10^{5}	3.75×10^{5}	3.53×10^{5}	2.30×10^{5}			4.91×10^{3}	3.16×10^{3}	1.03×10^{3}			2.00×10^{2}
DGO2-1	5.47×10^{5}	4.97×10^{5}	4.64×10^{5}	2.92×10^{5}	2.63×10^{5}	2.51×10^{5}	1.55×10^{5}			3.43×10^{3}	2.16×10^{3}	9.49×10^{2}			5.28×10^{1}
2	1.16×10^{6}	1.13×10^{6}	1.06×10^{6}	6.48×10^{5}	6.18×10^{5}	5.36×10^{5}	3.70×10^{5}	3.44×10^{5}		7.72×10^{3}	4.94×10^{3}	1.90×10^{3}			1.78×10^{2}
3										Too hot	Too hot	5.57×10^{5}		9.74×10^{4}	9.69×10^{4}
DGO3-1	1.77×10^{6}	1.79×10^{6}	1.58×10^{6}	9.72×10^{5}	9.30×10^{5}	8.58×10^{5}	5.38×10^{5}	5.28×10^{5}		1.22×10^{4}	7.38×10^{3}	3.22×10^{3}			4.32×10^{2}
DGO4-1	5.36×10^{5}	5.32×10^{5}	4.80×10^{5}	3.07×10^{5}	2.89×10^{5}	2.58×10^{5}	1.71×10^{5}		3.57×10^{3}		1.82×10^{3}	7.80×10^{2}			2.04×10^{1}
DGO5-1												2.06×10^{5}		3.45×10^{4}	3.48×10^{4}
DGO6-1	7.38×10^{5}	7.38×10^{5}	6.72×10^{5}	4.48×10^{5}	4.02×10^{5}	3.65×10^{5}	2.39×10^{5}	2.35×10^{5}		4.21×10^{3}	3.41×10^{3}	9.55×10^{2}			1.57×10^{2}
2										6.85×10^{5}	3.91×10^{5}	1.72×10^{5}		1.72×10^{4}	1.73×10^{4}
DGO7-1												1.06×10^{5}		1.36×10^{4}	1.28×10^{4}
DGO9-1	7.32×10^{5}	7.15×10^{5}	6.42×10^{5}	4.32×10^{5}	3.92×10^{5}	3.81×10^{5}	2.31×10^{5}	2.29×10^{5}		5.03×10^{3}	2.77×10^{3}	1.19×10^{3}			1.41×10^{2}
DGO11-1	1.51×10^{6}	1.50×10^{6}	1.39×10^{6}	9.49×10^{5}	8.22×10^{5}	7.80×10^{5}	5.09×10^{5}			1.00×10^{4}	6.30×10^{3}	2.40×10^{3}			1.63×10^{2}
DGO12-1	4.36×10^{5}	4.25×10^{5}	4.07×10^{5}	2.47×10^{5}	2.41×10^{5}	2.13×10^{5}	1.37×10^{5}			3.28×10^{3}	1.80×10^{3}	7.75×10^{2}			6.96×10^{1}
DGI1-1	1.36×10^{5}	1.36×10^{5}	1.15×10^{5}	8.16×10^{4}	7.45×10^{4}	6.59×10^{4}	3.99×10^{4}			9.37×10^{2}	8.52×10^{2}	3.03×10^{2}			
DGI2-1	1.96×10^{5}	1.96×10^{5}	1.76×10^{5}	1.13×10^{5}	9.78×10^{4}	9.96×10^{4}	6.06×10^{4}				1.04×10^{3}	3.41×10^{2}			6.24×10^{1}
DGI3-1										1.09×10^{3}	6.96×10^{2}	2.02×10^{2}			4.5×10^{1}
DGNUL-1						Too hot	Too hot		Too hot		Too hot	5.29×10^{5}		7.40×10^{4}	7.29×10^{4}
DGSUL-1						6.96×10^{5}	4.04×10^{5}		9.25×10^{3}		5.11×10^{3}	2.09×10^{3}			4.04×10^{2}
DGSC-1						5.11×10^{5}	3.12×10^{5}		7.00×10^{3}		3.91×10^{3}	1.48×10^{3}			1.87×10^{2}
DGSLR-1						8.22×10^{5}	5.4×10^{5}		1.16×10^{4}		6.25×10^{3}	2.66×10^{3}			2.32×10^{2}
DWNUL															5.67×10^{3}
DWNUL-1						3.71×10^{5}							1.12×10^{4}	1.14×10^{3}	9.80×10^{2}
DWNC															3.53×10^{3}
DWNC-1						3.56×10^{5}							1.10×10^{4}	8.00×10^{2}	5.87×10^{2}
DWNLR															7.21×10^{4}
DWNLR-1						4.79×10^{5}							1.11×10^{4}	7.18×10^{2}	6.89×10^{2}
DWSUL															7.38×10^{3}
DWSUL-1						3.03×10^{5}							7.17×10^{2}		7.29×10^{3}
DWSC-1													7.99×10^{2}	5.53×10^{2}	3.78×10^{2}
DWSLR															3.74×10^{5}
DWSLR-1						2.47×10^{5}							6.34×10^{2}	5.50×10^{2}	3.53×10^{2}

TABLE C.2 —SUMMARY OF FALLOUT DEPOSITION MEASUREMENTS

(Shot Shasta: beta activity, dis/min/sq ft)

Sample	D + 1.84	D + 1.90	D + 1.98	D + 2.20	D + 2.30	D + 2.37	D + 2.52	D + 2.59	D + 2.68	D + 2.75
SGO1-1										
SGO1-2	4.16×10^{7}	3.31×10^{7}	3.30×10^{7}	2.98×10^{7}	2.94×10^{7}	2.84×10^{7}	2.73×10^{7}	2.58×10^{7}	2.53×10^{7}	2.26×10^{7}
SGO1-3										
SGO2-1	1.26×10^{8}	1.24×10^{8}	1.22×10^{8}	1.00×10^{8}	1.04×10^{8}	1.16×10^{8}	1.05×10^{8}	9.25×10^{7}	8.66×10^{7}	8.50×10^{7}
SGO2-2	4.00×10^{7}	3.16×10^{7}	3.14×10^{7}	2.63×10^{7}	2.73×10^{7}	2.63×10^{7}	2.51×10^{7}	2.46×10^{7}	2.31×10^{7}	2.28×10^{7}
SGO2-3										
SGO3-1										
SGO3-2										
SGO3-3										
SGO4-1										
SGO4-2	6.68×10^{7}	6.14×10^{7}	5.52×10^{7}	5.20×10^{7}	5.13×10^{7}	5.09×10^{7}	4.85×10^{7}	3.23×10^{7}	4.43×10^{7}	4.04×10^{7}
SGO4-3										
SGO5-1										
SGO5-2										
SGO5-3	5.79×10^{7}	4.93×10^{7}	4.74×10^{7}	4.39×10^{7}	4.23×10^{7}	4.19×10^{7}	3.92×10^{7}	3.79×10^{7}	3.66×10^{7}	3.51×10^{7}
SGO6-1	3.41×10^{7}	2.58×10^{7}	2.96×10^{7}	2.63×10^{7}	2.22×10^{7}	2.23×10^{7}	2.08×10^{7}	2.03×10^{7}	1.94×10^{7}	1.82×10^{7}
SGO6-2	5.05×10^{8}	2.82×10^{8}	2.95×10^{8}	2.66×10^{8}	1.61×10^{8}	3.01×10^{8}	3.01×10^{8}	2.99×10^{8}	3.05×10^{8}	4.86×10^{8}
SGO6-3					4.08×10^{8}					
SGO7-1										
SGO7-2				9.17×10^{8}	9.79×10^{8}		9.36×10^{8}	9.86×10^{8}	1.21×10^{9}	1.23×10^{9}
SGO7-3	3.88×10^{7}	2.98×10^{7}	2.84×10^{7}	2.54×10^{7}	2.50×10^{7}	2.46×10^{7}	2.31×10^{7}	2.31×10^{7}	2.21×10^{7}	2.14×10^{7}
SGO8-1										1.09×10^{9}
SGO8-2										
SGO8-3										
SGO9-1										
SGO9-2										
SGO9-3	2.66×10^{7}	2.68×10^{7}	2.56×10^{7}	2.26×10^{7}	2.13×10^{7}	2.21×10^{7}	2.06×10^{7}	2.03×10^{7}	1.91×10^{7}	1.91×10^{7}
SGO10-1	2.99×10^{7}	2.86×10^{7}	2.71×10^{7}	2.41×10^{7}	2.51×10^{7}	2.41×10^{7}	2.33×10^{7}	2.11×10^{7}	2.16×10^{7}	2.16×10^{7}
SGO10-2	3.14×10^{7}	3.01×10^{7}	2.86×10^{7}	2.68×10^{7}	2.58×10^{7}	2.56×10^{7}	2.36×10^{7}	2.28×10^{7}	2.26×10^{7}	2.12×10^{7}
SGO10-3	3.56×10^{7}	3.46×10^{7}	3.26×10^{7}	3.06×10^{7}	2.99×10^{7}	2.91×10^{7}	2.81×10^{7}	2.63×10^{7}	2.53×10^{7}	2.51×10^{7}
SGO11-1	3.01×10^{7}	2.96×10^{7}	2.76×10^{7}	2.61×10^{7}	2.46×10^{7}	2.33×10^{7}	2.30×10^{7}	2.13×10^{7}	2.13×10^{7}	2.08×10^{7}
SGO11-2										1.10×10^{9}
SGO11-3										
SGO12-1						1.52×10^{8}	9.12×10^{7}			
SGO12-2										
SGO12-3										

Sample	D + 3.14	D + 3.27	D + 3.43	D + 3.60	D + 3.79	D + 4.40	D + 4.80
SGO1-1							
SGO1-2	2.13×10^{7}	1.96×10^{7}	1.88×10^{7}	1.81×10^{7}	1.68×10^{7}	1.46×10^{7}	1.33×10^{7}
SGO1-3							
SGO2-1	7.61×10^{7}	6.76×10^{7}	6.21×10^{7}	5.94×10^{7}	6.02×10^{7}	4.82×10^{7}	4.51×10^{7}
SGO2-2	1.93×10^{7}	1.88×10^{7}	1.78×10^{7}	1.68×10^{7}	1.56×10^{7}	1.36×10^{7}	1.20×10^{7}
SGO2-3							
SGO3-1						1.39×10^{9}	1.29×10^{9}
SGO3-2							
SGO3-3							
SGO4-1							
SGO4-2	3.79×10^{7}	2.76×10^{7}	3.36×10^{7}	3.18×10^{7}	2.96×10^{7}	2.51×10^{7}	2.36×10^{7}
SGO4-3							
SGO5-1							
SGO5-2					7.42×10^{8}	4.39×10^{8}	3.92×10^{8}
SGO5-3	3.04×10^{7}	2.96×10^{7}	2.84×10^{7}	2.66×10^{7}	2.53×10^{7}	2.18×10^{7}	1.81×10^{7}
SGO6-1	1.63×10^{7}	1.58×10^{7}	1.51×10^{7}	1.41×10^{7}	1.38×10^{7}	1.10×10^{7}	1.03×10^{7}
SGO6-2	2.98×10^{8}	2.60×10^{8}	2.47×10^{8}	2.34×10^{8}	2.21×10^{8}	1.90×10^{8}	1.72×10^{8}
SGO6-3							
SGO7-1							
SGO7-2	1.24×10^{9}	1.23×10^{9}	1.19×10^{9}	1.14×10^{9}	1.08×10^{9}	9.04×10^{8}	8.16×10^{8}
SGO7-3	1.88×10^{7}	1.76×10^{7}	1.68×10^{7}	1.60×10^{7}	1.51×10^{7}	1.36×10^{7}	1.20×10^{7}
SGO8-1	1.29×10^{9}	1.32×10^{9}	1.28×10^{9}	1.26×10^{9}	1.21×10^{9}	1.05×10^{9}	9.40×10^{8}
SGO8-2							
SGO8-3	1.21×10^{9}	1.29×10^{9}	1.37×10^{9}	1.30×10^{9}	1.24×10^{9}	1.08×10^{9}	9.66×10^{8}
SGO9-1							
SGO9-2							
SGO9-3	1.65×10^{7}	1.53×10^{7}	1.51×10^{7}	1.46×10^{7}	1.36×10^{7}	1.10×10^{7}	1.05×10^{7}
SGO10-1	1.76×10^{7}	1.78×10^{7}	1.65×10^{7}	1.56×10^{7}	1.48×10^{7}	1.28×10^{7}	1.13×10^{7}
SGO10-2	1.88×10^{7}	1.76×10^{7}	1.71×10^{7}	1.63×10^{7}	1.51×10^{7}	1.33×10^{7}	1.18×10^{7}
SGO10-3	2.13×10^{7}	2.11×10^{7}	1.96×10^{7}	1.88×10^{7}	1.76×10^{7}	1.48×10^{7}	1.33×10^{7}
SGO11-1	1.86×10^{7}	1.65×10^{7}	1.63×10^{7}	1.51×10^{7}	1.43×10^{7}	1.20×10^{7}	1.10×10^{7}
SGO11-2	1.29×10^{9}	1.29×10^{9}	1.26×10^{9}	1.20×10^{9}	1.14×10^{9}	9.71×10^{8}	8.80×10^{8}
SGO11-3	1.22×10^{9}	1.31×10^{9}	1.14×10^{9}	1.40×10^{9}	1.25×10^{9}	1.07×10^{9}	9.98×10^{8}
SGO12-1	1.26×10^{9}	1.31×10^{9}	1.34×10^{9}	1.27×10^{9}	1.31×10^{9}	1.11×10^{9}	1.03×10^{9}
SGO12-2						1.42×10^{9}	1.28×10^{9}
SGO12-3						1.42×10^{9}	1.26×10^{9}

Sample	D + 5.40	D + 6.39	D + 7.36	D + 8.71	D + 16	D + 17	D + 37	D + 233	D + 506	D + 534
SGO1-1								3.14×10^{7}	9.49×10^{6}	7.61×10^{6}
SGO1-2	1.10×10^{7}	9.28×10^{6}	7.77×10^{6}	6.29×10^{6}	2.28×10^{6}			7.76×10^{4}	1.77×10^{4}	1.97×10^{4}
SGO1-3								3.50×10^{7}	1.05×10^{7}	8.77×10^{6}
SGO2-1	4.08×10^{7}	3.41×10^{7}	2.73×10^{7}	1.83×10^{7}	6.52×10^{6}			3.03×10^{5}	8.32×10^{4}	7.92×10^{4}
SGO2-2	1.05×10^{7}	8.04×10^{6}	7.03×10^{6}	5.79×10^{6}	3.32×10^{6}		7.18×10^{5}	7.25×10^{4}	1.20×10^{4}	1.26×10^{4}
SGO2-3								3.66×10^{7}	1.14×10^{7}	9.08×10^{6}
SGO3-1	1.22×10^{9}	1.04×10^{9}	8.66×10^{8}	6.97×10^{8}				1.33×10^{7}	3.33×10^{6}	3.24×10^{6}
SGO3-2								2.20×10^{7}	5.75×10^{6}	5.67×10^{6}
SGO3-3								1.96×10^{7}	5.31×10^{6}	4.93×10^{6}
SGO4-1								2.61×10^{7}	6.50×10^{6}	5.74×10^{6}
SGO4-2	2.06×10^{7}	1.63×10^{7}	1.31×10^{7}	1.10×10^{7}	3.45×10^{5}		1.32×10^{6}	1.32×10^{5}	3.31×10^{4}	3.54×10^{4}
SGO4-3			1.10×10^{9}	9.21×10^{8}				1.77×10^{7}	3.61×10^{6}	3.32×10^{6}
SGO5-1								1.89×10^{7}	3.73×10^{6}	3.59×10^{6}
SGO5-2	3.42×10^{8}	2.48×10^{8}	2.02×10^{8}	1.67×10^{8}			1.86×10^{7}	4.77×10^{6}	9.70×10^{5}	9.90×10^{5}
SGO5-3	1.71×10^{7}	1.38×10^{7}	1.13×10^{7}	8.78×10^{6}		2.59×10^{6}		9.75×10^{4}		1.95×10^{4}
SGO6-1	8.78×10^{6}	7.26×10^{6}	6.29×10^{6}	4.51×10^{6}	1.65×10^{6}		6.45×10^{5}	4.23×10^{4}		1.20×10^{5}
SGO6-2	1.49×10^{8}	1.23×10^{8}	1.17×10^{8}	8.62×10^{7}			1.46×10^{7}	1.75×10^{6}		3.10×10^{5}
SGO6-3			1.12×10^{9}	9.16×10^{8}				1.57×10^{7}	3.04×10^{6}	2.65×10^{6}
SGO7-1								5.01×10^{7}	1.84×10^{7}	5.32×10^{6}
SGO7-2	7.15×10^{8}	4.12×10^{8}	3.42×10^{8}	2.82×10^{8}				5.59×10^{6}	1.60×10^{6}	1.25×10^{6}
SGO7-3	9.79×10^{6}	8.27×10^{6}	6.76×10^{6}	5.71×10^{6}		1.74×10^{6}		3.83×10^{4}		1.43×10^{4}
SGO8-1	8.11×10^{8}	4.70×10^{8}	4.00×10^{8}	3.23×10^{8}				6.52×10^{6}	1.86×10^{6}	1.63×10^{6}
SGO8-2								3.09×10^{7}	8.89×10^{6}	7.53×10^{6}
SGO8-3	8.20×10^{8}	4.54×10^{8}	3.81×10^{8}	3.05×10^{8}				8.54×10^{6}	2.66×10^{6}	2.46×10^{6}
SGO9-1								1.41×10^{7}	4.48×10^{6}	3.76×10^{6}
SGO9-2				1.17×10^{9}				1.57×10^{7}	5.30×10^{6}	4.43×10^{6}
SGO9-3	9.05×10^{6}	7.26×10^{6}	6.02×10^{6}	4.78×10^{6}	1.72×10^{6}		6.25×10^{5}	3.60×10^{4}		9.75×10^{3}
SGO10-1	1.03×10^{7}	8.55×10^{6}	7.03×10^{6}	5.28×10^{6}	3.49×10^{6}		6.72×10^{5}	4.08×10^{4}		1.14×10^{4}
SGO10-2	1.05×10^{7}	8.27×10^{6}	6.76×10^{6}	5.52×10^{6}	1.95×10^{6}		6.84×10^{5}	5.55×10^{4}		9.00×10^{3}
SGO10-3	1.16×10^{7}	9.29×10^{6}	8.04×10^{6}	6.29×10^{6}	2.24×10^{6}		8.23×10^{5}	6.29×10^{4}		1.37×10^{4}
SGO11-1	1.01×10^{7}	7.77×10^{6}	6.52×10^{6}	5.01×10^{6}		1.51×10^{6}		6.83×10^{4}		1.29×10^{4}
SGO11-2	7.61×10^{8}	4.31×10^{8}	3.66×10^{8}	2.97×10^{8}			4.93×10^{7}	6.52×10^{6}	1.76×10^{6}	1.71×10^{6}
SGO11-3	8.66×10^{8}	4.93×10^{8}	4.16×10^{8}	3.42×10^{8}			6.72×10^{7}	8.42×10^{6}	2.32×10^{6}	1.40×10^{6}
SGO12-1	9.16×10^{8}	5.17×10^{8}	4.47×10^{8}	3.66×10^{8}				5.78×10^{6}	1.48×10^{6}	1.35×10^{6}
SGO12-2	1.19×10^{9}	9.44×10^{8}	8.15×10^{8}	6.83×10^{8}				9.32×10^{6}	2.54×10^{6}	2.22×10^{6}
SGO12-3	1.21×10^{9}	1.00×10^{9}	8.38×10^{8}	6.88×10^{8}				6.52×10^{6}	2.67×10^{6}	2.23×10^{6}

TABLE C.2 — (Continued)

Sample	D + 16	D + 22	D + 37	D + 233	D + 506	D + 527	D + 534	D + 576
SGO1						7.75×10^5		
SGO2						6.65×10^5		
SGO3						8.12×10^5		
SGO4						7.59×10^5		
SGO5						8.53×10^5		
SGO6						8.69×10^5		
SGO7						7.81×10^5		
SGO8						8.07×10^5		
SGO9						6.06×10^5		
SGO10						5.93×10^5		
SGO11						6.08×10^5		
SGO12						5.32×10^5		
SGI1						5.90×10^2		
SGI1-1	1.42×10^5		5.54×10^4	5.39×10^3			8.71×10^1	
SGI1-2	1.58×10^5		6.12×10^4	4.97×10^3			1.03×10^2	
SGI1-3	1.94×10^5		8.16×10^4	6.48×10^3			0	
SGI2						9.22×10^2		
SGI2-1	1.09×10^5		4.48×10^4	3.18×10^3			6.66×10^1	
SGI2-2	1.06×10^5		5.49×10^4	5.72×10^3			7.81×10^1	
SGI2-3	1.16×10^5			4.20×10^3			8.23×10^1	
SGI3						1.18×10^3		
SGI3-1	1.30×10^5		5.44×10^4	4.37×10^3			9.79×10^1	
SGI3-2	1.00×10^5			3.42×10^3			3.30×10^1	
SGI3-3	1.46×10^5		6.12×10^4	6.78×10^3			1.59×10^2	
SGNUL						1.06×10^6		
SGNUL-1				5.74×10^7	2.08×10^7		1.59×10^7	
SGNUL-2				2.98×10^7	1.42×10^7		7.10×10^6	
SGNUL-3				5.36×10^7	1.72×10^6		1.63×10^7	
SGNC						6.97×10^5		
SGNC-1				5.16×10^7	8.40×10^6		1.20×10^7	
SGNC-2				1.97×10^7	6.28×10^6		4.66×10^6	
SGNC-3				9.55×10^7			2.52×10^7	
SGNLR						3.59×10^4		
SGNLR-1				4.00×10^7	1.48×10^7		1.19×10^7	
SGNLR-2				3.76×10^7	1.27×10^7		1.08×10^7	
SGNLR-3				2.03×10^7	7.13×10^6		6.14×10^6	
SGSUL						9.08×10^5		
SGSUL-1				1.25×10^7	3.66×10^6		3.00×10^6	
SGSUL-2	4.39×10^6			1.33×10^5	3.14×10^4		8.00×10^6	
SGSUL-3				2.84×10^7	7.85×10^5		2.38×10^6	
SGSC						1.26×10^6		
SGSC-1				2.54×10^7	6.84×10^6		9.01×10^6	
SGSC-2			3.38×10^7	6.72×10^6	1.67×10^6		1.72×10^7	
SGSC-3				6.64×10^7	2.26×10^7		1.76×10^6	
SGSLR						1.13×10^6		
SGSLR-1				3.11×10^7	1.34×10^7		5.94×10^6	
SGSLR-2				1.06×10^7	2.52×10^6		6.98×10^6	
SGSLR-3				4.43×10^7	9.00×10^6		4.00×10^4	
SGNCL						1.19×10^6		
SGNCL-1								
SGNCL-2								
SGNCL-3								
SWNUL								
SWNUL-1		2.10×10^4		2.87×10^3	6.86×10^2		1.34×10^3	1.35×10^3
SWNC								
SWNC-1		2.30×10^4		2.98×10^3	1.08×10^3		8.43×10^2	8.50×10^2
SWNLR								
SWNLR-1		2.23×10^4		3.75×10^3	1.51×10^3		1.10×10^3	1.09×10^3
SWSUL								
SWSUL-1		1.44×10^4		2.50×10^3	5.83×10^2		4.39×10^2	4.46×10^2
SWSLR								
SWSLR-1		1.55×10^4		1.61×10^3	2.56×10^2		5.87×10^2	5.9×10^2

Appendix D

GAMMA-ENERGY DETERMINATIONS

TABLE D.1 —SUMMARY OF GAMMA ENERGY DETERMINATIONS LUCITE ABSORBER COLUMNS

Shot Diablo ,

	Outside (H + 12 to H + 120)			Inside (H + 12 to H + 55)			Inside (H + 55 to H + 120)		
Absorber position	Gamma dose, mr	Half value thickness, cm	Energy, Mev	Gamma dose, mr	Half value thickness, cm	Energy, Mev	Gamma dose, mr	Half value thickness, cm	Energy, Mev
Zero 1				960	6.25	0.275	385	21.5	3.6
2				445			320		
3				260			260		
4				170			230		
North 1	29,060	4.65	0.105	1,280	7.20	0.39	480	16.1	2.2
2	6,300			720			385		
3	3,000			440			280		
4	1,420			295			250		
East 1	14,640	9.15	0.68	1,510	6.80	0.345			
2	6,900			810					
3	4,450			470					
4	9,125			320					
South 1	3,650	8.45	0.58	1,330	6.95	0.36	500	18.9	2.9
2	2,440			730			400		
3	1,510			430			330		
4	1,040			280			280		
West 1	2,680	9.25	0.72	1,240	7.40	0.42	490	20.3	3.25
2	1,580			690			390		
3	1,080			410			330		
4	760			295			295		

Shot Shasta

	Outside (H + 0 to H + 177.5)			Inside (H + 0 to H + 78.5)			Inside (H + 78.5 to H + 177.5)		
Absorber position	Gamma dose, mr	Half value thickness, cm	Energy, Mev	Gamma dose, mr	Half value thickness, cm	Energy, Mev	Gamma dose, mr	Half value thickness, cm	Energy, Mev
Zero 1				3,810	4.75	0.115	450	9.15	0.69
2				2,000			330		
3				840			160		
4				450			50		
North 1	*			2,560	5.40	0.18	587	5.80	0.22
2	*			1,260			320		
3	*			693			150		
4	4,060			450			115		
East 1	*			2,810	5.00	0.15	560	3.82	
2	*			1,320			245		
3	7,310			693			80		
4	3,460			460			40		
South 1	*			2,480	4.70	0.105	370	12.3	1.3
2	*			1,140			290		
3	5,310			587			215		
4	2,400			380			115		
West 1	*			2,320	4.87	0.125	460	4.63	0.10
2	*			1,140			280		
3	*			560			80		
4	7,310			370			60		

*Film too dense to read.

Appendix E

AIR-DUST CONCENTRATION MEASUREMENTS

TABLE E.1 —SUMMARY OF AIR-DUST CONCENTRATION MEASUREMENTS

		Concentration, dis/min/m^3							
		0–10 min	10–20 min	20–30 min	30–40 min	40–50 min	50–60 min	60–70 min	70–80 min
Shot Diablo									
Counted at D + 29	Outside	4.2×10^7	4.8×10^4	2.17×10^5	2.66×10^5	1.59×10^5	4.75×10^4	5.3×10^4	3.17×10^4
	Inside	9.5×10^6	4.0×10^4	4.3×10^4	3.15×10^4	6.5×10^4	4.4×10^4	9.2×10^4	4.75×10^4
Counted at D + 38	Outside	6.4×10^4	1.07×10^3	3.6×10^3	4.3×10^3	2.13×10^3	8.8×10^2	7.7×10^2	9.9×10^2
	Inside	1.45×10^5	1.61×10^3	1.8×10^3	1.47×10^3	2.7×10^3	1.42×10^3	2.28×10^3	2.04×10^3
Extrapolated to time of collection	Outside	4.5×10^9	1.43×10^7	3.4×10^7	2.95×10^7	1.22×10^7	3.05×10^6	2.9×10^6	1.35×10^6
	Inside	1.1×10^9	2.12×10^6	1.53×10^6	8.3×10^5	1.41×10^6	8.1×10^5	1.5×10^6	7.0×10^5
Shot Shasta									
Counted at D + 16	Outside	3.15×10^5	2.59×10^4	2.75×10^4	3.3×10^4	4.69×10^4	2.12×10^4	1.27×10^4	1.16×10^4
	Inside	1.01×10^3	1.22×10^3	2.89×10^3	1.95×10^3	1.33×10^3	1.98×10^3	1.55×10^3	6.75×10^2
Counted at D + 29	Outside	1.11×10^5	8.2×10^3	1.07×10^4	1.19×10^4	1.63×10^4	6.92×10^3	4.58×10^3	3.99×10^3
	Inside	3.3×10^4	4.17×10^2	1.01×10^3	6.51×10^2	4.31×10^2	6.38×10^2	5.99×10^2	2.87×10^2
Extrapolated to time of collection	Outside	7.96×10^9	1.74×10^8	9.88×10^7	8.05×10^7	8.63×10^7	2.93×10^7	1.44×10^7	1.07×10^7
	Inside	2.55×10^7	8.19×10^6	1.04×10^7	4.76×10^6	2.45×10^6	2.75×10^6	1.76×10^6	6.22×10^5

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